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Strategic Outreach for Nuclear Workforce Pipeline Development and Maintenance at a Historically Black College University (HBCU)

Dr. Antony Kinyua, Morgan State University

Dr Kinyua is an Associate Professor of Nuclear Science and currently affiliated to the Physics and Engineering Physics Department at Morgan State University (MSU) as a Lecturer. He teaches Physics, Engineering Physics and Earth Sciences. He has more than 30 years experience in College teaching and research utilizing Nuclear and Related Analytical Techniques (NRATs) in material analysis, climate and environmental pollution monitoring.

Ezana Negusse
Richard Damoah
Maajida Murdock
Dr. Oludare Adegbola Owolabi P.E., Morgan State University

Dr. Oludare Owolabi, a professional engineer in Maryland, joined the Morgan State University faculty in 2010. He is the assistant director of the Center for Advanced Transportation and Infrastructure Engineering Research (CATIER) at Morgan State Universit

Jonathan Wilson, Morgan State University

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Abstract

Our HBCU has a well-established record of providing a wide array of quality college and pre-college programs in most academic disciplines in the state. We present the development and implementation of our activities that are designed to increase the number of underserved minority students interested in STEM programs in nuclear science and technology. The impact of our activities in addressing challenges and providing skills developed and utilized in the implementation of Experiment-Centric Pedagogy (ECP) framework has led us to innovative and practical solutions. Our initial activities include experiential learning and research, using advanced nuclear technology, exposure to professionals working in the nuclear energy industry, and provision of skills to K-12 teachers, parents and adult family members to work with and encourage their children in STEM activities and nuclear science programs. These activities have resulted in deeper, sustained student engagement and understanding of mitigating factors that our students face and need to be addressed to enhance a nuclear workforce pipeline at an HBCU.

Introduction

In the USA, Historically Black Colleges and Universities (HBCUs) continue to award a large share of bachelor's degrees to African American students in Science, Technology, Engineering, Arts and Mathematics (STEAM). HBCUs are also the baccalaureate origins of one-quarter to one-third of black science and engineering (S&E) doctorate recipients [1]. However, as shown by the National Science Foundation data [2] for college aged population (18-24 years), black students only comprise 14.9% with B.Sc. degree recipients consisting of 2% in the geosciences, 2.6% in physics and 3.9% in engineering. There is, therefore, a great need for HBCUs to play an increasing role in their nation-wide prevalence in these fields [3]. It is estimated that the United States faces a shortage of almost 200,000 people with “deep analytical skills”, as well as “1.5 million managers and analysts to analyze big data and make decisions based on their findings” [4].

The Board on Higher Education and Workforce (BHEW) at the USA National Academies of Sciences Medicine and Engineering (NASEM) has also continued to provide the academic community, policymakers, and businesses with insights and recommendations on critical higher education and workforce issues facing our nation [5]. BHEW previously identified that the educational outcomes and STEM readiness of students of color will have direct implications on America’s economic growth, national security, and global prosperity [6]. The recent Report by BHEW (2022) has identified seven (7) strategies: (i) Dynamic, multilevel, mission-driven leadership; (ii) Institutional responsiveness to student needs; (iii) Campus climates that support a sense of belonging for students; (iv) Student-centered academic and social supports; (v) Effective mentorship and sponsorship; (vi) Undergraduate research experiences; (vii) Mutually beneficial public- and private sector partnerships. The same report has also made four (4) recommendations: (i) Leadership; (ii) Public-and Private-Sector Partnerships; (iii) Financial Investments and Support for Institutional Research Capacity, and (iv) Performance Measures and Accountability.

To address the development and implementation of the above goals, our HBCU team together with some other Majority Institutions and private sector, proposed to the Department of Energy (DOE) a manpower development project proposal designed to increase the number of underserved minority students interested in STEM programs in nuclear science and technology. This is because there is a great need to identify existing and future gaps in the nuclear energy workforce and to bring to the pool of trained workforce from the minority students graduating from our HBCUs. In addition, the nuclear energy workforce gap analysis in the USA is expected to include the full range of existing and potential variations in U.S. nuclear reactor technologies (current and future) plus the nuclear fuel cycle. Our proposal is now funded and will cover labor pools associated with uranium supply, enrichment and fuel fabrication, fission reactors, recycling, interim storage, and final disposal.

In the years to come, having a steady supply of technicians, operators, engineers, and other subject matter experts will help to ensure the safe and reliable running of nuclear power plants. Developing and maintaining the next generation of nuclear energy experts will require a workforce pipeline from the HBCUs to serve the present light water reactor fleet; advanced reactor development, construction, operation, and maintenance; and other areas of the nuclear fuel cycle, including those aspects that do not currently exist in the United States.

Our project will use the results of the gap analysis to develop responses and strategies to address workforce pipeline needs. These responses are multicomponent and do incorporate all team members from five institutions and DOE. The outcomes will act as templates for the development of curricula, courses, certificates, experiences, and opportunities to initiate, develop, and train the future nuclear workforce in our institutions and the country at large. It is expected that outcomes developed by our project team will act as templates for similar activities that in the future can be supported by industry, the federal government, or public/private partnerships. The contributions made by the team members are being utilized in the gap analysis and the workforce training outcomes.

The need for the research and work under this project cannot be overlooked. In November 2021, BWX Technologies announced a build-out and upfit for a manufacturing and research and development center adjacent to an existing facility [7]. This addition of close to 100 jobs is coupled with over a $65 million investment for the next three years. This facility will serve BWTX activities in its nuclear services group and the division that designs and produces microreactors and nuclear fuels for space exploration and national security. This work is primarily for U.S. government agencies. This workforce investment was noted locally. *"BWXT's continued investments in the commonwealth are a testament to our world-class higher education* *institutions and talented workforce,"* Virginia Governor Ralph Northam said in a statement. *"When we invest in people, companies invest in Virginia — and that is exactly what has happened. We look forward to BWXT's continued success"*[7]. It should be noted that job training at no cost to the company will be provided through the Virginia Jobs Investment Program. This demonstrates a recognized need for a technical nuclear workforce. The benefits from this workforce are evident. Furthermore, the potential for public support for workforce training is available. The outcomes from this proposal can be leveraged in the future for supported training opportunities.

In addition, in November 2021, an article discussed a nuclear workforce skill shortage in the United Kingdom [8]. This article describes a path forward for addressing the workforce gap that may be instructive for our project. The article describes the need for a nuclear workforce pipeline to achieve the nation's net-zero carbon emissions goal. It calls for the evaluation of the workforce to determine if it is available for the nuclear power generating ambitions of the United Kingdom. The article points out a decade pause in developing nuclear power generation in the United Kingdom. These conditions require a revitalization of the nuclear workforce to provide the United Kingdom with the capabilities that it desires. The article clearly states there is an ever-growing skill gap between the desired projects and the workforce needed to complete these projects. For the United Kingdom, this workforce problem has been exacerbated by Brexit and an aging workforce. Conditions are much harder for accessing specialists and skilled workers needed in the expected new nuclear enterprise. The article also points out that this is true for thousands of other well-paid jobs in technical areas that will compete with nuclear power generation. If not addressed, there is a potential risk that the United Kingdom would be relying upon external markets for their nuclear technology workforce.

Many countries and international organizations have addressed workforce issues in the past. These studies provide an opportunity to learn from previous evaluations and compare their estimates with actual results. For our project, evaluating existing data is part of tasks and are an important consideration in the gap analysis. Summaries of a few of these reports are provided below as examples in this introduction section.

In 2011, the International Atomic Energy Agency (IAEA) developed a document on nuclear workforce planning for member states [9]. The goal of the publication was to help Member States develop an effective workforce plan at both the organizational and national levels. This was to be achieved by providing a structured approach that allows the nations to estimate their nuclear power program's human resource needs, assess their current level of capability, identify competence gaps, and plan how to fill those gaps based on the nature and scope of their nuclear power programs. The management of this information, the knowledge that individuals require as part of their competence requirements for assigned activities, as well as the additional knowledge they gain while performing those duties, is an important component of good human resource management. Throughout the course of the IAEA nuclear energy program, this knowledge is required by numerous generations of workers. As a result, the IAEA technical document also discusses the importance of developing a proper knowledge management system inside the nuclear energy program, as well as the benefits of doing so to secure the program's long-term viability. The IAEA report is targeted to member states developing a nuclear power program than for those with an established program. As such, it may have limited applicability to the current and evolving state of the nuclear industry in the United States.

In 2012, the National Academy developed a document on the US-based nuclear and radiochemistry expertise [10]. The report was produced in response to the growing use of nuclear medicine, the potential expansion of nuclear power generation, and the pressing need to protect the country from external nuclear threats, maintain our nuclear weapons stockpile, and manage the nuclear wastes generated in previous years.

The above considerations necessitate a large, well-trained, and exceptionally talented workforce that our HBCUs can contribute to. The demand for and supply of nuclear and radiochemistry experts, a key component of this workforce, was evaluated. Considering a variety of plausible future scenarios, none of these fields were expected to see a decline in demand for knowledge, which is largely true. However, many people in the current industry were nearing retirement age in 2012, and the number of students interested in nuclear and radiochemistry employment had dropped considerably in recent decades. Increased student interest in these vocations, increased research and instructional capacity of universities and colleges, and sector-specific on-the-job training were expected to be required to avoid a gap in these vital areas. The NRC 2012 [10] document also provided proposals for avoiding a future scarcity of nuclear and radiochemists. The demand for nuclear and radiochemists was conservatively projected in the nuclear energy and power sector, including the USNRC and state regulatory agencies. National laboratory requirements, some of which will be in the energy and power sector, are not included in these estimates. The report’s findings stated that under a scenario of continued operation of nuclear power plants at current capacity, there is a critical need for nuclear and radiochemistry expertise in nuclear energy and power generation, especially at the B.Sc. level. The findings went on to state there is a considerable need for B.Sc. chemists with a specialization in nuclear and radiochemistry in the nuclear power industry. According to predictions from the nuclear power industry in the United States, there will be a demand for roughly 274 B.Sc. chemistry graduates with a focus on nuclear or radiochemistry during the next 20 years. The nuclear power industry now conducts most of its training for nuclear or radiochemistry skills among nuclear power operators in-house. The nuclear power industry has a modest demand for nuclear and radiochemists with graduate degrees at the M.Sc. and Ph.D. levels, while federal and state regulatory bodies have a large demand. Over the next 20 years, there is an expected demand for 36 M.Sc. and 38 Ph.D. level nuclear and radiochemists in the nuclear energy and power sector, excluding work at national laboratories. While these 2012 insights are useful, there is a need to “benchmark” the findings against the changes in the nuclear sector over the following decade. In addition, there is a need to expand the findings to consider including the role of HBCUs in a broader range of engineering, science, and other disciplines required by the nuclear sector.

In 2013, the National Academy also produced a report on workforce trends in the United States energy and mining sector [11]. This report is inclusive of all energy sources and includes a section on nuclear energy. In this report, nuclear energy was identified as a mature sector along with oil, gas, and mining. The report considered the current systems of nuclear power generation in the United States, primarily pressurized water reactor systems and boiling water reactor systems. The overall fraction of electric power production by nuclear power in the United States was identified at 20%. Four sectors in the nuclear power industry were identified: nuclear waste facilities, nuclear power plants, nuclear fuel facilities, and nuclear-decommissioning activities. The workforce needs for each sector were identified and discussed.

Methods

To train, encourage and motivate students to pursue nuclear science and technology careers and jobs in our communities, our HBCU team has been assigned Task 4.2: ***Strategic Outreach for Nuclear Workforce Pipeline Development and Maintenance***. The objectives include the following:

1. Increase the number of historically underserved and underrepresented students interested in nuclear science and technology, engineering and DOE specific STEM careers.

2. Engage students in hands-on experiential learning and research, using advanced nuclear science technology, exposure to professionals working in the nuclear energy industry, and

3. Provide skills to parents and adult family members to work with and encourage their children in STEM activities and nuclear science programs.

Our HBCU team will also provide an additional node for the Office of Technology Transfer so as to promote the concept of business application of nuclear reactor technology and research to faculty, staff and students, encourage and support the development of new and innovative nuclear technology products.

Metrics of Focus Areas for Strategic Outreach

The metrics to be used to assess effectiveness of strategic outreach efforts as shown Outcomes in Table 1. Our initial activities include (i) experiential learning and research, (ii) using advanced nuclear technology, (iii) exposure to professionals working in the nuclear energy industry, and (iv) provision of skills to K-12 teachers, parents and adult family members to work with and encourage their children in STEM activities and nuclear science programs [12].

First, our project will use the results of the gap analysis to develop responses and strategies to address workforce pipeline needs. These responses are multicomponent and do incorporate all team members from five institutions and DOE. Secondly, to address the development and implementation of the stated goals, our HBCU team together with some other Majority Serving Institutions (MSI) and private sector, proposed and got funded by the Department of Energy (DOE) a manpower development project proposal that is designed to increase the number of underserved minority students interested in STEM programs in nuclear science and technology. It is therefore hoped that the outcomes will act as templates for (i) the development of curricula, courses, certificates, experiences, and (ii) opportunities to initiate, develop, and train the future nuclear workforce in our institutions and the country at large.

Table 1: Project Tasks Overview [12]

	Tasks	Outcomes
Meta-Analysis	Task 1-1: Lessons-learned from previous workforce evaluations in the nuclear industry Task 1-2: Lessons-learned from previous workforce evaluations in critical support fields Task 1-3: Leveraging and updating best practices for workforce evaluations	• Foundational analysis to synthesize insights from and applicability of previous nuclear workforce evaluations • Assessment of state of workforce in critical support fields and industries competing for skilled workers • Establishment of strategies and practices to guide subsequent project activities
Strategic Outreach	Task 2-1: Industry, national laboratory, and government agencies Task 2-2: Potential workforce/workers Task 2-3: Universities, educational institutions, and training agencies	• Identification of needs, challenges, and opportunities across organizations involved in the nuclear industry/fuel cycle • Understand workforce demand parameters and expectations • Identify workforce/worker expectations • Leveraging education and training to link supply with demand
Projection & Assessment	Task 3-1: Projected readiness and timelines for multiple scales and reactor technologies Task 3-2: Projected needs/changes across nuclear fuel cycle Task 3-3: Gap analysis/specification of workforce needs (with uncertainty)	• Integrated gap analysis to establish workforce needs accounting for (1) insights from industry, (2) projected future of nuclear reactor technologies/fuel cycle, and (3) the potential for other industries to compete for skilled workers • Assessment of uncertainty in future needs through scenario-based planning
Content Development	Task 4-1: Incorporation of gap analysis results into opportunity context Task 4-2: K-12 content development Task 4-3: Community college and trade schools Task 4-4: Undergraduate and postgraduate education Task 4-5: Re-training, cross-training and certification Task 4-6: General Purpose	• Translation of insights from gap analysis into strategic plan for content development • Development of formal educational content and enrichment programs for K-12 schools, community colleges, trade-schools, undergraduate, and post-graduate programs • Creation of content to facilitate transition of experienced skilled workers and tradespersons to the nuclear sector • Development of general educational content to communicate the advantages of nuclear power and the possibilities of a nuclear career

As explained above and shown in Table 1 our Task 4 translates insights from the gap analysis (and associated uncertainties) into actionable content for engaging a diverse pool of workers. Specifically, this task will develop representative and targeted educational content for K-12, the community college, trade school, undergraduate, and post-graduate programs. A focus will be on the training of new workers as well as re-training workers that may be displaced by other sectors. General educational content intended to increase community awareness of the benefits of nuclear power and opportunities for employment in the nuclear sector will also be created. These tasks will be performed from months 0 to 36 of the project as follows and simultaneously within each task. Tasks will be initiated and ramp up during their expected timeframe. The tasks may be extended based on activities and direction from the team.

Task	Proposed Project Months
1	0-18
2	9-33
3	12-36
4	6-36

Project Efforts

Our project efforts that are new are shown in Table 1 [12]. Specifically, Task 4 is for our HBCU participation and implementation. It encompasses content development - courses, lectures, and hands-on opportunities. Task 4 also transforms the gap analysis' findings and associated uncertainty into practical information for a diverse workforce. This assignment will generate representative and targeted instructional content for K-12, community colleges, trade schools, undergraduate, and post-graduate programs. The training of new workers as well as the retraining of individuals who may be displaced by other industries will be prioritized. There will also be general educational content generated to raise community knowledge of the benefits of nuclear electricity and job prospects in the nuclear sector.

Task 4 will incorporate the gap analysis results into opportunity content. From the previous tasks a statement of needs, leveraging existing best practices, and establishing appropriate content by grade-level, school type, and technical skill will be achieved. The content is expected to extend from K-12 to graduate level. The re-training and cross-training of workers, including the development of a certificate program, will be a factor within Task 4. This will include introducing workers with the correct technical skills to the nuclear industry. The efforts in this task will also include online modules, internships and practicums, and knowledge transfer. Efforts will be made to set up a centralized clearinghouse. One possibility is to partner with Oak Ridge Institute for Science and Education (ORISE) and other existing programs. The audience target for this effort will be wide, from K-12 to graduate level. For knowledge transfer, interactions with industrial partners are expected. The knowledge transfer can include job training, participation in outreach, mentorship, and documentation of experience from experts. This can include video documentation that can be incorporated into online media distribution and massive open online courses.

Task 4 is composed of six subtasks listed as follows:

- Task 4.1: Incorporation of gap analysis results into opportunity content
- Task 4.2: K-12 content development
- Task 4.3: Community college and trade schools
- Task 4.4: Undergraduate and postgraduate education
- Task 4.5: Re-training and cross-training
- Task 4.6: General purpose

These subtasks will be linked. The technical information will be developed by the team members and parsed into the different subset areas based on the content need, target audience, and delivery methods. Key components to be expressed in the educational efforts in Task 4 include the use of mathematics, basic atomic and nuclear science, concepts in radiation safety, and interaction with and detection of radioactive material.

A key feature in Task 4 will be the development of nuclear science activities among the proposal members. The nuclear reactor and the radiochemistry laboratories at our partner universities [12] will be used to provide educational opportunities and the development of materials for further outreach to the broad community of the potential workforce. Students from the HBCU partner will be engaged at our partner universities. It is expected these activities will occur during the summer of the projects, where the visiting HBCU students will be engaged in educational and laboratory activities that encompass handling radioactive material, detection of radiation, analysis related to practices in the nuclear industry, and assessment of the science and technology of fuel cycle activities. The team has budgeted funds for supporting HBCU students to develop Task 4 content using the partner radiochemistry laboratories. These activities are expected to include radiation detections, handling of radioactive materials, and fuel cycle laboratory activities. The team will provide material across all the subtasks based on the summer interaction activities.

For each subtask there will be a statement of needs, leveraging of existing best practices, and establishing appropriate content by grade-level and school type. Task 4.6 will include online modules, internships and practicums, knowledge transfer, mentorship, and documentation of experience from experts. For recorded information, setting up a centralized clearinghouse, including partnering with ORISE and other existing programs, is This task will develop and implement activities designed to increase the number of traditionally underserved and underrepresented minority students interested especially in nuclear science and STEM programs in general. Identifying and developing outreach activities that will increase awareness and interest in nuclear energy science and needs for workforce development will be an expected outcome. This task will also develop curriculum and courses that will engender and motivate sustained interest in nuclear energy science among middle and high school minority students. These curriculum enrichment activities for middle and high school students will be developed to inform and expose students to various aspects of the nuclear energy cycle; to encourage participation in different enrichment activities during school year and in summer camps. The experiences at our partner universities with our HBCU students will be the basis for developing the activities with Tasks 4.2 to 4.6. This task will also include participation from Impact Allies Inc, which has experience and expertise in Task 4 areas.

An expected ultimate outcome of Task 4 is to organize and facilitate Regional or National pre-college nuclear energy workforce pipeline workshops or working conferences in 2 or 3 regions of the United States. These workshops will focus on informing and motivating underrepresented minority students to participate and become certified professionals in different aspects of nuclear energy science.

Task Relevancy [12]

This proposal is now federally funded and will identify existing and future gaps in the nuclear energy workforce. This gap analysis will explore all aspects of the U.S. nuclear fuel cycle and should be inclusive of labor pools associated with uranium supply, enrichment and fuel fabrication, fission reactors, recycling, interim storage, and final disposal.

It is important to note that through the above proposed tasks, our project aims to provide DOE-NE with a comprehensive nuclear energy workforce development plan to address identified gaps, challenges, needed resources, and opportunities to create these pipelines. Our project will assess and collect a range of data from workforce stakeholders. This input will be used to address workforce supply and demand, identifying the gaps and developing a pipeline for the workforce. The analysis will also address the expectations of the workforce and how these may impact the pipeline. A key aspect of the pipeline development in our project is the inclusion of K-12. Introducing nuclear concepts and ideas to this education level will increase the interest in nuclear technology at the more advanced levels and increase an understanding of the employment opportunities within the nuclear enterprise. This project will also develop and implement activities designed to increase the number of traditionally underserved and underrepresented minority students interested especially in nuclear science and STEM programs in general. Our project team includes inputs from business management, economic analysis, nuclear engineering, radiochemistry, K-12 education, nuclear power generating industry and technical education development.

Overview of Focus Areas, Specific Aims, Activities and Timeline

Table 2 shows an overview of the focus areas, specific aims, activities and proposed timeline. It is drawn from five (5) Task 4 goals: (i) Focus on K-16 STEM pipeline reinforcement, undergraduate and graduate level activities, development of new academic programs and certificate courses, (ii) Professional Development (PD) for K-16 teachers and administrators (both in per-son and online/remote), (iii) In-Classroom Implementation, (iv) Weekend Classes and Family Forum, and (v) Outreach and Field Trips.

Table 2: Overview of Focus Areas, Specific Aims, Tasks and Timeline

Goal	Specific Aim	Activity	Timeline (Months)
1. Focus on K-16 STEM pipeline reinforcement, undergraduate and graduate level activities, development of new academic programs and certificate courses.	i. Increase the number of traditionally underserved and underrepresented minority students interested especially in nuclear science and STEM programs in general. ii. Curriculum enrichment activities for middle and high school students will be developed to inform and expose students to various aspects of the nuclear science and technology to encourage participation in different enrichment activities during the school year and in summer camps.	i. Hands-on learning and teaching utilizing **E**xperiment **C**entric **P**edagogy (ECP) modalities [12],[13],[14],[17]. ii. Identifying /developing outreach activities to middle and high schools that will increase awareness and interest in nuclear science and technology needs for workforce development.	6-36
2. Professional Development (PD) for K-16 teachers and administrators (both in person and online/remote).	i. Introduce teachers to different aspects of nuclear science to incorporate them in their school teaching activities. ii. Introduction to nuclear science, engineering and technology, how to access "Navigating Nuclear" the K-16 curriculum by ANS, how to integrate the classroom activities in Navigating Nuclear into regular classroom STEM engagement or local STEM curriculum and scope sequence. iii. hands-on interactive materials will be assembled (STEM kits) for participating schools or classrooms.	i. Nuclear Engineering Scientists and personnel will present directly to the teachers and via recorded seminars and workshops. ii. Presenters for the PDs will come from STEM faculty at the partner colleges and universities as well as nuclear industry, e.g., NuScale power. iii. PD participants will also be introduced to relevant STEM education materials from USEPA and NASA education websites to augment those from ANS.	i. In-person and /or virtual sessions will be conducted every quarter (i.e., 4 times/year).

Goal	Specific Aim	Activity	Timeline (Months)
	iv. Navigating Nuclear is the K-12 curriculum by ANS. The classroom resources provided at the ANS website are aligned with NGSS and will be adapted accordingly. v. Utility of academic materials from International Atomic Energy Agency (IAEA) developed curriculum activities to be used in addition to simulation virtual labs to provide students real world/near world practical experiences in working with various nuclear technologies. vi. Facilitate attainment of some of the objectives of the American Nuclear Society (ANS). vii. Organize and implement/facilitate Regional or National Nuclear energy workforce pipeline workshops or working conferences for both pre-college and undergraduate levels, in 2 or 3 regions of the United States. viii. To work with nuclear science professionals and other industry experts in developing grade appropriate interactive hands-on nuclear science educational materials for both pre-college and undergraduate levels. This will involve university faculty, nuclear industry experts and members of societies such as: American Nuclear Society (ANS), American Chemical Society (ACS), etc.	iv. Participants in the PDs will be given stipends as incentives. v. Curriculum and course development spearheaded by the teachers and participating teams to engender/ motivate sustained interest in nuclear energy science and technology among middle and high school minority students. vi. Captivate the public; highlight the many benefits that nuclear technology brings to people's lives every day; drive enthusiasm for nuclear technology through K-16 STEM education; make nuclear science and technology curriculum available to every student in the U.S.; advocate for and invest in nuclear science, engineering, and technology careers; promote student engagement and developing future leaders and cultivate grassroots efforts to enable effective communications between members, the public, and policymakers (www.ans.org). vii. Establishment of a Young American Nuclear Scientist (YANS) society/group that will comprise of high school and middle school students interested in nuclear science. viii. Graduate and senior undergraduate students to serve as Nuclear Energy Science	i. In-person and /or virtual sessions will be conducted every quarter (i.e., 4 times/year).

Goal	**Specific Aim**	**Activity**	**Timeline (Months)**
	ix. Getting our students to gain access to internet tours of reactors in selected (partner campuses and industries) to learn some basic reactor operations in-person or over the internet (i.e., remotely).	Ambassadors (NESA) to assist with implementation of outreach to precollege students, parents and family members. ix. Workshops to focus on informing and motivating a diverse population of students, especially underrepresented minority students, to participate and become certified professionals in different aspects of nuclear science and technology.	
3. In Classroom Implementation	i. Various aspects of the Navigating Nuclear curriculum activities will be used in selected middle and high schools to enhance the quality and rigor of the school science and math or STEM curriculum.	i. Schools in our MUREP-SEMAA program will self-select navigating nuclear activities, and the teachers will receive professional development prior to the start of the in-classroom activities. ii. All nuclear science, engineering and technology activities selected for these outreach activities will be aligned with the school system's scope and sequence (as much as possible). iii. The project aims at providing Nuclear Science, Engineering and Technology (NSET) instruction to the students.	i. Twice a week for at least 4 weeks each semester.

Goal	Specific Aim	Activity	Timeline (Months)
4. Weekend Classes and Family Forum	i. Classes will be conducted for middle (grades 6-8) and high school (grades 9-12) students at our campus during fall and spring semesters. ii. Family involvement will be part of a direct outreach to parents and adult family members of students in the Saturday classes. iii. We will organize a family involvement forum that will meet virtually or in-person. iv. Family forum will be interactive and engaging for family members to learn about different aspects of the nuclear energy science and technology industry. v. During the family forum sessions, parents and guardians will attend hands-on workshops and seminars to obtain access to information and training designed to increase their ability to assist their children with math and science activities and the use of technology, as well as increase parental involvement in the student learning experience. vi. Parents will also participate in group discussions centered around the nuclear energy industry and workforce needs. This will equip parents with knowledge they need to better advice and counsel their children in considering nuclear engineering careers.	i. Emphasis will be on hands-on experiential learning in a fun and relaxing environment. We will draw activities from the ANS 'Navigating Nuclear" curriculum as well as other related STEM sites such as NASA and DOE. ii. Students who successfully complete the classes will be awarded certificates of completion. iii. Instructors for these classes will be recruited from STEM faculty at participating universities as well as the nuclear industry.	i. Classes will meet on Saturdays for 2 or 3 hours of instruction for 5 or 6 weeks per semester. ii. Family involvement forum that will meet virtually or in-person every other week (at least 3 times a semester).

Goal	Specific Aim	Activity	Timeline (Months)
5. Outreach and Field Trips	i. We propose hosting on our Campus a one-week summer day nuclear energy Camp for middle and high school students (one for each grade). ii. The "Nuclear Energy Scholars'" will participate in a 5-day immersion of all things nuclear in a grade appropriate mode. iii. Participants will be awarded certificates of completion at the end of the summer camps. iv. Details of the instruction and curriculum activities are to be determined by the team and teachers who underwent the PD training. v. These scholars will participate in virtual or in-person field trips during the summer camps. vi. Virtual field trips within the Navigating Nuclear curriculum will be incorporated into the different outreach activities during the school day and in the weekend classes. vii. Where possible, in-person field trips will be arranged to nuclear plants at a university campus or nuclear industry. viii. Expos on Nuclear Energy, Science and Technology. The main goal of these Expos will be to inform families about the importance of nuclear energy science engineering and technology; the workforce needs of this industry; provide them	i. These expos will be held once a year in 2 or 3 different regions of the country. ii. Participating universities will collaborate to implement these expos with Campus playing a lead role in the facilitation of the expos. iii. Presenters and exhibitors for the expos will come from national and federal laboratories and institutions relating to nuclear science and engineering as well as nuclear energy companies and universities with nuclear capabilities and programs. iv. ANS and other nuclear societies will also be part of the exhibitor pool. v. Invitations will be sent out to potential exhibitors. vi. The events will be widely publicized in different media including social media and the press so that families from a wide spectrum of society will be able to register and participate in the expos.	i. The expo events will last for about 4 to 8 hours.

Goal	Specific Aim	Activity	Timeline (Months)
	with easy-to-understand educational materials about nuclear energy and how they can encourage their children to pursue studies in this field.		

Activity Details

The goals, specific aims and program of activities are now shown in Table 2. Specifically, the Weekend classes will meet on Saturdays for 2 or 3 hours of instruction for 5 or 6 weeks per semester. Emphasis will be on hands-on experiential learning in a fun and relaxing environment. We will draw activities from the ANS "Navigating Nuclear" curriculum as well as other related STEM sites such as NASA and DOE. Students who successfully complete the classes will be awarded certificates of completion. Instructors for these classes will come from STEM faculty at our campus plus our collaborating universities as well as the nuclear industry.

Assessment and Evaluation Plan

As shown in Table 1 above, the assessment and evaluation of our project will be based on the outcomes. Our team is tasked with Task 4 that has four outcomes. Task 4 will use the insights from the other project tasks to inform content development [12].

Specifically, Task 4 will begin with first, translation of insights from the gap analysis into a strategic plan for content development. The development of formal educational content and enrichment programs for K-12 schools, community colleges, trade-schools, undergraduate, and post-graduate programs is an expectation. This content may include courses, lectures, and hands-on opportunities over multiple technical levels. It is expected that this content will result in content that can be transitioned into actual educational opportunities that can be accredited or certified and used for workforce training and enhancement. The diverse experience of our project team will permit tuning of the technical information to a range of levels.

Secondly, our task will also create content to facilitate the transition of experienced, skilled workers and tradespersons to the nuclear sector. This is expected to be an important consideration as the electrical generation section is expected to move from fossil fuel to non-CO_2 emitting power generation. The current fossil fuel workforce represents an opportunity (both for workers and the industry) as these workers may be able to transition to other energy sectors. Transitioning workers will need to understand and appreciate fundamental concepts of nuclear technology and the overall culture of nuclear power generation and operations. To assure a robust future workforce pipeline, the development of general educational content to communicate the advantages of nuclear power and the possibility of a nuclear career is also an outcome within Task 4.

Thirdly, our task is to include online modules, internships and practicums, and facilitated knowledge transfer sessions. Efforts are being made to set up a centralized clearinghouse. One possibility is to partner with Oak Ridge Institute for Science and Education (ORISE) and other existing programs. The audience target for this effort will be wide, from families, K-12 to graduate level. For knowledge transfer, interactions with industrial partners are expected. The knowledge transfer can include job training, participation in outreach, mentorship, and documentation of experience from experts. This can include video documentation that can be incorporated into online media distribution and massive open online courses.

It is therefore hoped that Task 4 plus our team activities [12] will provide a useful tool for evaluation by professionals, education programs and activities in our institutions and governmental bodies to help train the next group of nuclear engineers, scientists and technologists from our minority students in HBCUs. This is especially for those of us who aim to benefit and to improve the education delivery, nuclear data retrieval and analysis, digital information knowledge, effective institutional linkages that can enhance mutual research and development of minority human resources to promote capacity building and our national security especially through economic success.

Conclusion

The issues discussed in this paper have found their way into our nation's education and technological forums, industry, and policy think tanks. Our national academy of sciences, national councils for science and technology, industrial research and development institutes, institution of engineers among other professional bodies, non-governmental organizations (NGOs), community-based organizations continue reaching out through our various university programs and activities, many professional societies and the private sector. It is therefore hoped that our team activities will provide a useful resource to professionals, education programs and activities in our institutions and governmental bodies to help train the next group of nuclear engineers, scientists and technologists from our minority students in HBCUs. This is especially for those of us who aim to benefit and to improve the education delivery, nuclear data retrieval and analysis, digital information knowledge, effective institutional linkages that can enhance mutual research and development of minority human resources to promote capacity building and our national security especially through economic success. Our concerted efforts are still being challenged by some *otherism* [16] and contextual factors that continue to remind us to be humble, patient, persistent and to have faith in the resilience of our communities.

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