Getting Technical: Introducing Students to Technical Concepts for Nuclear Science and Policy to Create and Encourage Diversity in the Nuclear Field

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Abstract

When discussing diversity, it is important to consider the many of the types of diversity: gender diversity, racial diversity, religious diversity, cultural diversity, and diversity in abilities. The nuclear field has recently seen a surge in the diversity within the entire industry, but there is still room for the industry to grow in those areas. Where does that begin? How does that develop? When is the right time to engage the next generation of nuclear professionals? What topics should be introduced to encourage and foster excitement in the nuclear field? These questions are all certainly important but narrowing in on the topics that should be introduced might prove to be a very effective way to grow excitement in and, then, diversity in the nuclear field. Students at all socioeconomic levels should be introduced to various technical concepts that correspond to the stage and level of education that is appropriate for those students. Oftentimes there may be a speaker at a school for certain ages that will provide an overview of the nuclear industry as a whole, or perhaps even specifics on what that person does, but rarely is the interaction carried on over a long period of time and rarely do presentations for these students introduce technical concepts. Creating new, effective volunteer programs in a wide range of schools in local areas where nuclear sciences are supported would allow professionals in the nuclear field to identify and focus on students whose aptitude might lean them towards future careers in the nuclear field. This paper will focus on potential, effective ways to start these programs, and it will identify a range of technical concepts that might be considered as age-appropriate or that can be molded to fit individual schools and would, in turn, begin to develop a diverse base of students to grow and enter the nuclear field.

Background and Purpose for Development

The Nuclear field is one of the many fields that has a high percentage of workers approaching retirement age. As that generation leaves the industry there is a hope that technically sound and dedicated workers will have filled the vacancies left by those individuals. "In recent years, the subjects of science, technology, engineering, and mathematics (STEM) have been at the forefront of U.S. education due to growing concerns that American students are unprepared for the 21st century workforce and global economy. Improvements in STEM education have also been cited as "Critical to building a just and inclusive society," as STEM participation and achievement are particularly low in women and minorities. Attracting, retaining, and better educating larger and broader populations of students necessitates a focus not only on improving achievement in STEM but also on building interest in the disciplines" [1] With a potential human resource shortage on the horizon, the nuclear industry needs to find young, enthusiastic, and diverse professionals to move the industry forward. To create the most diverse and enthusiastic workforce, to two important questions need to be answered:

1. How does the nuclear industry create and encourage that enthusiasm?
2. How does the nuclear industry establish programs that support long-term diversity in the workforce?

A program that includes a focus on diversity from the onset will continue to do so throughout. Successful educational programs will provide a curriculum that excites and challenges students in various technical aspects of nuclear science and nuclear nonproliferation. Since it is important to find students ready for the challenges and the complexity in the nuclear field, technical topics should be introduced at an early age but also at a level that is equal to the abilities of the students. Additionally, since one of the goals of this educational program will be to challenge students and to find those that have a passion as well as the aptitude for nuclear science, it will be best to introduce these programs in areas with strong support for the nuclear industry.

These technical topics should be concepts that can either build on itself or be independent of other areas of the curriculum (i.e., it should not be necessary to have started the program from its inception and be exclusive to those that have been in the program from an earlier age). Generic, yet still technical, topics will be introduced in the middle school or junior high school years and more advanced topics will be introduced in the high school years. Unfortunately, there is not an exact program to mirror for this at the national laboratories, so this program will be a first-of-its-kind developing these specific topics at these levels of technical merit.

Creating Diverse Student Involvement

This leads to another interesting question: which students should be engaged or brought into this program? How would those students be chosen? In other similar STEM programs, students who have already shown an aptitude for math and science are selected for inclusion. However, this approach often leads to a less-diverse pool of students. To eliminate those biases and be inclusive, the program should be introduced in a variety of schools that have a diverse population of students. We recommend that the program be introduced in three different school systems: one in a suburban school system, one in an inner-city school system, and one in a rural school system. The Knoxville area near the Oak Ridge National Laboratory is a prime location for this program to be initiated. The Oak Ridge Schools have long been supporters of nuclear science and already have programs established that this program would be able to be integrated with as well as providing those students with a more comprehensive nuclear science background. The inner-city Knoxville schools as well as the rural schools in the surrounding counties to Oak Ridge National Laboratory include a very diverse student population and would introduce nuclear science and policy to many students who may not have exposure to nuclear science and policy otherwise. These students are a target population for this program. Other similar STEM programs in the past have, perhaps inadvertently, excluded students in lower income brackets [2]. Additionally, students who may not have been yet identified as having aptitude for science and math or for the social sciences that exist within the nuclear nonproliferation field would be reached through inclusion in this program.

Developing a Successful Technical Education Program

There are numerous STEM programs in public school systems, yet there are still fewer students pursuing careers in STEM fields. What are the factors that cause this reluctance to go into these fields? As noted in past studies, "[r]esearch related to students' ability beliefs in STEM has primarily focused on self-efficacy in STEM classes and to a lesser extent, students' self-concept (while these two constructs are related, measures of self-concept are often more general than those of self-efficacy, which typically reside at task level). Prior work in STEM education suggests that when students have confidence in their abilities in STEM classes as well as positive attitudes toward STEM, they are more likely to be interested in and ultimately pursue and persist in STEM-related courses and careers" [1] Therefore, providing a comprehensive program that allows students to grow and understand nuclear science while focusing on technical concepts should allow for success and the ability to build a fun program with enthusiastic students.

The next big question is, if enthusiastic students are more likely to stay in these programs and carry forward to a career in the nuclear field, then how can an educational program get students interested in and enthusiastic about nuclear science and nuclear nonproliferation? What would excite students? Most after-school STEM programs provide a general overview of various topics. Providing a technical, in-depth learning program can help transform the mindset of students such that they feel they are learning and contributing to the field. That ownership would allow them to thrive. When students receive positive feedback, they are encouraged to continue to learn more about those technical concepts and topics. This has been proven in the past with programs such as the Cyber Sleuth Science Lab. The lab incorporated a technical program to teach students more "real-world" concepts. The authors that reported on this program note that "[r]esearch shows that we learn best through a combination of theory and practice in a realistic context" and that "students learn science and critical thinking more effectively when applying knowledge and skills to authentic situations." [3]. This program would aim to apply similar "real-world" technical concepts to provide students challenges and instruction that simulates the kind of work they would have in jobs once they enter the workforce. A panel of college students at the recent Institute of Nuclear Materials Management Spent Fuel Management Seminar was asked when they initially become interested in the nuclear field and when did they first hear about the nuclear field? Each of the students noted that they were introduced to the nuclear field at a young age; however, they also noted that they did not realize their aptitude for nuclear science and a desire to pursue a career in the field until they were introduced to more technical concepts while in college. This reinforces that earlier introduction of technical concepts could encourage younger students to be interested in and pursue careers in the nuclear field, and if more students are reached through these technical programs, then there is a higher likelihood that more students will eventually accept jobs in the field.

Engaging students early with STEM has been shown to lead more students to be interested in a STEM career. For example, a study was done in Oregon with 134 students in grades 4-12. The students participated in an afterschool STEM program, and they completed a Common Instrument Suite survey before engaging with the afterschool program and then again afterward. The survey found a significant change in all the measured outcomes. The two results that had the most increase in percentage of positive responses were STEM interest, and STEM career knowledge. Specifically, in the career category, STEM career knowledge had the highest positive change. [4]

<u>Support for the Program</u>

The next concern is how top provide technical experts to convey the instruction for these programs. The first step would be to identify a pool of subject matter experts to participate. The experts need to be enthusiastic as well as excellent communicators. Students can tell when someone is excited about the information they are teaching, and students that are not encouraged and feel that they are not being supported in their learning are less likely to stick with after-school programs. [5] Next, specific schools would need to be selected for the program. This would be a selection process that includes presentations to schools about the program and allow the schools to accept the program as a viable after-school extracurricular activity. The experts would then be assigned their choice of a school and the programs would then be initiated. This process ensures that everyone is supportive of this not only as an after-school program but also as a program that aims to teach and direct students towards a future career.

For STEM programs to be successful, they "must have an after-school program dedicated to providing STEM learning opportunities and then prioritize and allocate resources for STEM professional development to staff […as well as] have meaningful STEM leaning beyond 'one-shot' experiences. After-school programs must occur regularly and provide consistent programming in STEM topics. The programs, when possible, must offer a continuum of STEM learning experiences in middle and high school to have a maximum impact." [6]

Programs such as these cannot be successful without financial support. Members of the nuclear community who would benefit from a program such as this would find it advantageous to provide funding for the setup of the program as well as for the time of the various experts who would be teaching at these after-school educational programs.

One of the potential collaborative opportunities with this program is to have it as an introductory program for schools offering nuclear engineering or nuclear policy courses with a specific focus on those colleges that are historically black colleges and universities. As the program matures, there could be opportunities created for those schools to specifically target students in these new technical educational programs for scholarships or other financial aid. Additionally, once these students move on to colleges, whether they are historically Black colleges and universities or other colleges with nuclear science or policy majors, there would be opportunities for students to then apply for internships with the departments and companies that are supporting the program and then have a direct return as these students in the program would be in the workforce as interns and then hopefully move into permanent positions after graduation.

As with any successful program, there would need to be an evaluation and feedback loop associated with this program. Understanding how the students are learning and if the students are maintaining enthusiasm will be essential to the success of the program. Again, if the purpose of the program is to encourage, teach, and prepare the next generation of nuclear workers there must be metrics to demonstrate that this is indeed happening. One of the drawbacks to this evaluation is that it cannot fully be realized for many years to see how many of the students within these programs continued on to study nuclear sciences or nuclear policy in college and then accept a professional position in the nuclear field.

Developing a Curriculum

Various topical nuclear science and nuclear nonproliferation topics would be excellent choices for inclusion in this type of program. Those areas include basic nuclear nonproliferation, nondestructive assay of nuclear materials, safeguards and security of nuclear materials, and nuclear and radioactive material transportation security and safety. A more detailed curriculum would be developed, but in general these topics would be broken down to discuss many of these specific technical concepts:

Basic Nuclear Nonproliferation

- Regulatory Bases for Nonproliferation
- Treaties
- Material Disposition

Nuclear and Radioactive Material Transportation Security and Safety

- Development of Security Programs
- Detection Techniques
    - Sensors and Electronic Tracking
    - Camera Technology
    - Radiation Monitoring
- Delay and Response
- Package Safety and Testing
    - Drop Testing
    - Test Instrumentation
    - Post-Test Examination

Nondestructive Assay of Nuclear Materials

- Gamma and Neutron Detection
- Detector Electronics and Pulse Processing
- Instrument Setup and Operation
- Measurement Statistics and Uncertainty

Safeguards and Security of Nuclear Materials

- Identification of Safeguards
- Facility Design
- Material Control and Accountability

Conclusions and Recommendations

Developing a new educational program using technical concepts and advanced science learning for students in middle and high school would provide a diverse pipeline for future workers in the nuclear science and nonproliferation fields. This program could be implemented at various schools in the area surrounding Oak Ridge National Laboratory to ensure diverse student involvement. The supporting research shows that utilizing these technical concepts for learning is the best way to get students interested and excited about the topics. Further efforts will be placed into the development of an after-school educational program in the nuclear science and nonproliferation topical areas using technical concepts that are age-appropriate yet challenging. Specific curriculum and topics would then be selected for an initial program.

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