2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33071

Project-based Learning Program for Nuclear Workforce Development Phase II: Implementation

Dr. Hayrettin Bora Karayaka, Western Carolina University

Bora Karayaka is an Associate Professor at the College of Engineering and Technology, Western Carolina University. He has worked as a Senior Engineer for smart grid and wireless communication industries for over ten years. He is currently responsible for teaching electric power engineering courses in the college.

Dr. Karayaka's research interests include power engineering education, energy generation, identification, modeling and control for electrical machines and smart grid. He received his B.S. and M.S. degrees from Istanbul Technical University in Control and Computer Engineering and his PhD degree in Electrical Engineering from The Ohio State University.

Dr. Chip W. Ferguson, Western Carolina University

Chip Ferguson is the Associate Dean of the College of Engineering and Technology and Professor of Engineering and Technology at Western Carolina University.

Dr. Amber C. Thompson, Western Carolina University

Amber C. Thompson is an Assistant Professor and Coordinator for Engineering Technology-Technical Operations Distance Program at Western Carolina University. She has a long history of research in customized training and workforce development in Western North Carolina. Dr. Thompson has four years of industrial experience and served in the NC community college system for ten years. She has also served on the local business advancement team for six years.

Dr. Thompson's research interests are workforce development, engineering graphics and prototyping, and human factors in engineering. She has an Ed.D. from Liberty University, an Ed.S. from Northwestern State University of Louisiana, an M.S.T. from Western Carolina University, a B.S. from Appalachian State University, and an A.A.S. from Isothermal Community College.

©American Society for Engineering Education, 2021

Project Based Learning Program for Nuclear Workforce Development
Phase II: Implementation

I. Abstract

Due to the predicted personnel needs for nuclear and power industries and related national security issues, it has become apparent that efforts must be put in place to prepare individuals for careers in these industries. One of the effective ways to ensure the personnel needs for the nuclear power industry and security are met in a timely manner is to promote educational programs that develop skills and knowledge in support of the workforce growth. Many more individuals from non-traditional sources must be recruited and trained than ever before if individuals are to become part of the nuclear workforce in the near future. Western Carolina University (WCU) serves diverse student populations (especially first-generation students) who have not historically entered careers in nuclear-related industries. Therefore, the project-based learning program presents an opportunity for education and training for students as part of the nuclear workforce development efforts.

Several years ago, WCU joined with Consortium of Universities for Sustainable Power (CUSP) as part of a country-wide partnership lead by University of Minnesota to attract and train students into careers in sustainable power. An engineering major with electrical power concentration was developed under the engineering program through which students could take various courses at WCU and to address the regional needs. To encourage interest in careers in nuclear power, attractive and highly competitive scholarships funded through a grant from Nuclear Regulatory Commission were offered to students at sophomore to senior levels. The scholarship was made available to students majoring in the Bachelor of Science in Engineering program with Electric Power, and Mechanical concentrations. Although the scholarships supported only a few students in the first semester of the program, other students who saw the benefits of such training also entered the program in following semester. Nuclear power related capstone projects were also adopted by students, increasing exposure to regulations, standards, management, and other aspects of nuclear power besides the technical program.

The initial efforts (Phase I) towards the NRC scholarship program and workforce development during the first year of implementation were published in 2019 ASEE conference proceedings. Here, we present the results of the first- and second-year efforts involving the implementation of the program (Phase II). Accounts involving students, both scholarship recipients and others, who have engaged in capstone projects related to the nuclear power industry are also discussed. The findings of the first- and second-year assessments on student outreach and educational goals are shared. We provide an update on the status of the program, and summarize lessons learned as a guide for other programs in support of nuclear workforce development.

II. Introduction

Workforce development in nuclear related energies is more important now than ever. According to U.S. Energy Information Administration (EIA) data on power plant operations, 9 of the 10 U.S. power plants that generated the most electricity in 2019 were nuclear plants[1]. This number has increased by 30% in just under ten years. In 2010, only 6 of the 10 plants generating the most

electricity were nuclear. Why the change? The makeup of power plants that generate the most electricity has shifted in the past 10 years from a mix of nuclear and coal plants to almost all nuclear in 2019[1]. It is inevitable that nuclear power will play a large role in sustaining the power demands of the US. Even with increased interest in alternative energies, the continuity of nuclear will be the only stable and reliable source when coal is phased out. The recent Texas crisis (weather event) is a wake-up call that exposes how the U.S. electric infrastructure may not be fully prepared to absorb steep climate-related spikes in demand for power[2]. The task for educational institutions is to develop personnel to satisfy the workforce demands parallel to the spike in nuclear energy demand. For years universities have let nuclear programs decline. The number of nuclear engineers and technicians graduating out of programs has been insufficient to meet current pressures much less the future demands[3]. At WCU, faculty recognized this shortfall and began the Nuclear Workforce Development Scholarship program funded by the Nuclear Regulatory Commission (NRC). The program is now in Phase II and has seen notable results.

Developing the nuclear workforce takes time. A substantial amount of competence has to be developed prior to taking on the challenges of the nuclear industry. For this reason, scholarship recipients are required to complete research endeavors, take extracurricular nuclear energy courses, join professional seminars, complete project-based learning activities, and attend field trips to nuclear or nuclear related facilities. In addition, students are required to complete a nuclear related internship during their time in the program to gain much needed experience. The scholarship program has rigorous checkpoints to ensure students are capable of handling the challenges of one of the most arduous engineering fields. In Phase II of the NRC scholarship program and workforce development implementation strategy, much consideration for skill and experience have been taken into account to fully prepare students to enter the realm of nuclear energy. The American Physical Society pointed out that there is also likely to be a severe shortage of nuclear scientists, engineers and technicians in several sectors of government responsible for regulatory, safety, or emergency response matters – both for the nuclear power industry and for other areas of national security concern (e.g. transportation and shipping)[3]. Consideration of these factors were taken into account when approving research projects and seeking potential employers in the nuclear industry. Upon completion of their degree in an engineering program with electric power or mechanical concentrations, these scholarship recipients are very marketable and have found success in the nuclear industry.

There are limited publications in the literature for the implementation of scholarship programs geared towards workforce development[4,5]. The contribution of this paper to engineering education is the fact that it points out the implementation activities conducted throughout the scholarship program and the strategies used to initiate successful program completion by all stakeholders.

III. Program Description

The WCU-NWD program engaged scholarship recipients in various academic and professional related activities in an effort to broaden and enhance their technical and professional skills. To this end, the recipients were required to complete a project-based learning core of courses, participate in professional development activities, and complete five separate technical courses with a power emphasis. The scholarship recipients were comprised of sophomore through senior-

level engineering students specializing in electric power and mechanical disciplines, jointly called EPME.

Applicants who were selected to participate in the program were required to agree and adhere to the terms of the scholarship program, which included the requirement to work in nuclear-related employment for 6 months for every complete or partial year of support awarded and to actively participate in institutional and program-level opportunities for professional and career development, such as professional guest speaker presentations, career development activities offered through university student support centers, and publishing their work in undergraduate academic forums. Coupled with these activities, participants were enrolled in at least three of the College of Engineering and Technology's project-based learning (PBL) courses, starting at the junior level. The PBL sequence included the following courses:

> ENGR 350 - Engineering Practices and Principles III - Engineering project-based learning (open-ended) with emphasis on project control and engineering design processes. Special emphasis will be placed on professional, ethical, global, environmental, and contemporary issues. Contact Hours: 2 Lecture, 2 Lab.
>
> ENGR 400 - Engineering Capstone I - Senior engineering project selection, planning, and development. Emphasis will be placed on defining project requirements, developing project work breakdown structure, conceptual designs, and working prototypes. 1 Lecture, 4 Lab.
>
> ENGR 450 - Engineering Capstone II - Senior engineering project design, development, fabrication, and testing. Emphasis will be placed on iterative design processes, project management and execution, fabrication and testing. 1 Lecture, 4 Lab.

The PBL sequence of courses provided the participants with an opportunity to learn project management, technical communication, teaming, and problem-solving skills while working on open-ended industry-based projects. The year-long senior capstone experience provided each program participant with opportunities to work on nuclear-related projects with local industries, network, and gain hands-on engineering experience in the field. These efforts were coordinated through WCU's Center for Rapid Product Realization, working with both faculty and industry mentors, and were funded by the supporting industry sponsors.

To provide further opportunities for the participants to increase their technical knowledge, they were required to study our Nuclear Power emphasis, which includes the following courses: 1) ENGR493-01 Special Topics-Distance Course #1, 2) ENGR493-02 Special Topics-Distance Course #2 3) ENGR 352 Thermodynamics and Heat Transfer, 4) EE 451 Electric Power Systems, 5) EE 452 Electric Machines and Drives. The courses 3, 4 and 5 above were offered in classroom by our engineering program. In collaboration with the Nuclear Power Institute at Texas A&M University, courses 1 and 2 were delivered online until Fall 2019, when they were unable to continue due to a restructuring of the institution. Since this time, we have offered these courses in a special-topics seminar format. With the advising faculty's guidance, students selected from these three courses: 1) Nuclear Power Plant Fundamentals, 2) Nuclear Power Plant

Systems (Pressurized Water Reactors), 3) Nuclear Power Plant Systems (Boiling Water Reactors). Mentorship and advisement were provided for course sequencing and selection.

The three WCU-NWD scholarship program directors served as the primary mentors and academic advisors for the participants. The directors organized group activities that sought to build a learning community and inform the participants of current events, such as: career services, tutoring services, guest speakers from the nuclear industry, site-tours, and other professional development activities. The directors also developed action plans for participants who did not maintain the requisite GPA, usually allowing one semester to improve. During this probationary semester, the directors ensured the student received an extra measure of support and mentorship, including increased tutoring and mentorship through institutional student success offices. In the event a participant's efforts to remediate their GPA within the probationary period failed, the student was dropped from the program, and a suitable replacement was sought from the scholarship application pool of applicants.

IV. Scholarship Program Activities

The implementation activities associated with our scholarship programs include various ways to engage the scholars with the engineering profession in support of nuclear-related industry. After the completion of each outreach and recruiting cycle, the annual program participant activities included the following:

a. New student orientation, student advising and registration
b. Mentoring & PBL/research activities to engage students
c. Extracurricular courses
d. Professional seminars/field trips
e. Progress and end of year mentor meetings
f. Evaluation activities.

There was a total of fourteen scholarship recipients who participated in these activities between Fall 2017 and Spring 2020 semesters. Their duration-of-participation differed depending on their recruiting term within their progress towards the major. For example, on one extreme some participated as many as five semesters and on another extreme, some participated only for two semesters. As of Spring 2020, nine out of fourteen participants graduated, and five participants are continuing towards completion of their major.

The following paragraphs summarize the activities a. through e. listed above. Evaluation activities are covered in section V.

IV-a. New student orientation, student advising and registration

Earlier in the beginning semester, new participants received their scholarship acceptance letter, where they were welcomed and invited to a New Participant Orientation session. In this session, the participants were presented with the detailed scholarship program requirements, milestones, registration guidance, and advising. The specific items of interest that were discussed included:

- Establishing an account with the school's financial aid office and setting expectations for the dates related to tuition/fees and refund
- Conveying initial information on PBL and research activities through ENGR350, ENGR400 and ENGR450 courses
- Encouraging extracurricular activities (field trips, mentoring meetings, tutoring for course help, progress meetings)
- Emphasizing continued efforts in meeting the eligibility criteria
- Advising for the courses to be taken

A Question and Answer session followed the presentation, where participants were encouraged to ask the PI/CO-PIs about any concerns or mis-understood procedures. In addition to the orientation, each participant met individually with the project personnel for detailed course scheduling and planning towards graduation, for each semester, during the institutionally established University Advising Day.

IV-b. Mentoring & PBL/research activities to engage students

The following paragraphs list the PBL projects completed through ENGR350, ENGR400 and ENGR450 courses. The ENGR350 course and associated projects were only required for those participants who did not complete this course prior to their recruiting date. The ENGR 350 course makes use of engineering project-based learning (open-ended) with an emphasis on project control and engineering design processes. The projects for the scholarship recipients were structured to include nuclear and energy related design concepts and principles, where they were required to address the need of a specific market segment in the relevant nuclear/energy field. The projects were coordinated, in general, with the course instructors so that the scholarship recipients were placed in the relevant project teams. After the instructors presented the various project ideas, the student selection process was determined by vote and ranking their top three projects. Therefore, it was not always feasible to place the appropriate ENGR 350 project with the relevant team of NRC scholars.

On the other hand, the ENGR400 and ENGR450 capstone project selection process was more flexible, which allowed for much more immersive and effective training for the workforce. The capstone projects were generally crafted by the project investigators and the logistics were provided by the Center for Rapid Product Realization at WCU. Feedback from industry and/or other experts in the field was sought during the project proposal stage or in the end, during the project presentation stage. Mentorship by the project personnel was provided throughout all PBL courses, although the dedication and involvement of the project mentor in the capstone courses were much more intense.

Two scholarship recipients successfully completed their capstone project course sequence (ENGR400 and 450) during the 2017-2018 academic year under the mentorship of the project PI. The results for the first phase were published/presented at the National Conference on Undergraduate Research (NCUR) 2018 meeting. The title of the poster presentation was "Load Following of a Nuclear Power Plant", where the focus was on the developed mathematical models[6]. Second phase results of this research, which included simulation studies, were presented in the school's Capstone Symposium. Another scholarship recipient worked on the

modeling and stability aspect of this project during the 2018-2019 academic year. The results of this project, conducted by this student in collaboration with the two other scholarship recipients, were presented in a paper session and published in 2019 IEEE Southeast Conference, Huntsville, AL[7].

In the 2018-2019 academic year, two more capstone projects were completed. The first one was the continuation of the previous year's capstone project, mentioned above, and mentored by the PI. The project's emphasis was more focused on modeling, stability analysis, as well as experimental implementation. The title of this presentation was "Design and Implementation of a Load Following Emulator for Nuclear Power Generation" and the focus was the experimental design and testing. In this phase of the study, a power electronics drive circuitry was designed to emulate a scaled down nuclear power plant with constant power output[8]. The results of this project were presented in a poster session and published in 2020 IEEE Southeast Conference, Raleigh, NC (a virtual conference).

The second project in the 2018-2019 academic year was entitled "A Model to Accurately Predict Hydrogen Explosion Severity in Nuclear Power Stations". The PI, in collaboration with a mechanical engineering faculty at WCU, determined this senior capstone project idea and mentored the students throughout the course of this project. The output of this project was a mathematical model that predicts the severity of gas explosions in nuclear reactors buildings that contain obstacles. The model was used for the direct implementation of the hydrogen explosion hazard and to design nuclear reactor buildings and vents to mitigate the effect of the explosion. Two NRC scholarship recipients majoring in the mechanical concentration of our Engineering program were placed on the same team. The results of this project were presented in Appalachian Energy Summit 2019 by these two team members, who received an honorable mention award for the undergraduate poster competition[9].

Two scholarship recipients completed their capstone project course sequence in 2019-2020 academic year under the supervision of the project PI. This project was cosponsored by NASA Glenn Research Center, where one scholar completed his internship in the 2019 summer term. The mentorship was provided by another subject expert faculty at WCU. An abstract of this project was submitted and accepted by NCUR 2020[10]. The title of this abstract was "Pumped Fluid Loop Thermal Management Design Proposal for NASA's Stirling Power Conversion System". Unfortunately, the conference was cancelled due to the ongoing concerns about the 2020 pandemic, but the abstract was subsequently published.

One scholarship recipient completed his capstone project course sequence during the 2019-2020 academic year under the mentorship of the project PI. Another scholarship recipient actively contributed to this project as well. An abstract of this project was submitted and accepted by NCUR 2020[11]. The title of this abstract was "Load Following Capability for Hybrid Nuclear and Solar Photovoltaic Power Plants with Energy Storage Systems". The conference was cancelled due to the ongoing concerns about the 2020 pandemic, but the abstract was subsequently published. In addition, expanded results of this undergraduate research study were submitted in a paper format and accepted by North American Power Symposium 2020[12].

All three project teams also received concurrent support from the Center for Rapid Product Realization for project related logistics and planning. Each of these projects were presented in the College of Engineering and Technology's capstone symposium and received feedback from the members of local industry, including Duke Energy, GE, and Eaton.

In terms of ENGR350 PBL activities, a project was completed by a scholarship recipient in during the Spring 2019 semester. This project was focused on experimentally designing a flywheel energy storage system. One scholar and her team members, which were from different engineering majors (with electrical and mechanical concentrations), successfully implemented and demonstrated the operation of this system. In their prototype system, multiple solar panels with a maximum power point tracker were utilized as the source of energy that drove the flywheel (due to the impracticality of including a nuclear generator at this level of education). The PI provided mentorship during this project.

Finally, two ENGR350 PBL activities were completed by two other scholarship recipients during the Fall 2019 semester. The first project was to design a portable hydroelectric generator. The design required that the unit could be safely placed into flowing water and that it generated enough power to charge a portable device that plugs into a 12-volt power supply. The device was designed to be waterproof, safe for the user during charging, as well as being lightweight and portable. The device would serve as a way to charge a cell phone or hand-held device during the day or night where there was a source of running water. The second project was about designing an outdoor thermoelectric cooler using a Peltier device. The system was designed to operate from solar PV panels and a battery. The specific enclosure, as well as PV panels and the battery, were sized to provide sustained cooling performance. The PI provided on demand mentorship during these projects. The posters for both projects were prepared and posted online for the annual Research and Scholarship Celebration, 2020 event, at WCU.

IV-c. Extracurricular course engagement activities

As explained in the program description section, the scholarship recipients are required to take an additional five courses, which define the nuclear power emphasis. During the advising days, the participants were scheduled to take these courses for the upcoming semesters. Scheduling and managing three face-to-face courses at the host institution was relatively straightforward. Efforts by the project personnel were made so that one or two of these onsite courses were counting towards the students' degree plan to minimize the course load. However, the logistics for the two on-line nuclear power courses, initially offered by Nuclear Power Institute (NPI) at Texas A&M University, were somewhat challenging. The PI scheduled weekly mentoring meetings with the participants to track the progress and facilitate the exam sessions. During the Fall 2019 semester, the institute stopped offering these courses due to its restructuring efforts. It was extremely unlikely to have these courses offered with the same level of rigor and coverage going forward. As a result, contingency plans were made to preserve the benefits to the scholarship recipients. The WCU courses were subsequently offered as special topics seminar courses where the topics, normally covered in the institute's courses, were presented in regular meetings by external experts (including regional industry), students, and faculty (the project PI). At the completion of the courses, the students were exposed to the same bodies of knowledge as well as a broader range of topics. The new course delivery formats also preserved the original

intent of the additional coursework. Students receiving the scholarships were projected to go beyond the regular curriculum and learn topics relevant to the nuclear industries. The assessment activities in these new courses were primarily conducted through presentation evaluation rubrics filled out by the faculty mentor as well as the students enrolled. As of Spring 2020 semester, all scholars, but one, successfully completed both courses either through the institute or WCU.

IV-d. Professional seminars/field trips

In March 2018, a professional seminar by a lead engineer from Duke Energy was provided to present the hydroelectric facilities in the western part of North Carolina. Larger scale hydroelectric facilities owned by Duke Energy are used to store nuclear power produced during the evening hours when demand is low and dispatched to the power grid during daytime when demand is high. In addition, the speaker provided some highlights about the company and work culture.

In November 2018, in collaboration with IEEE Western North Carolina section, there were two professional seminars provided to NRC scholars held in Biltmore Park facility (an hour away from the main campus).

- An expert from Schweitzer Eng. Labs presented a topic on Power System Communications. She is a well-known speaker in power system protection circles.
- An expert from Duke Energy presented a topic on New Gas Insulated Regional Substation. He is a professional engineer registered in North Carolina.

In May 2019, a professional seminar by Robert Pettigrew, who is a retired engineer with several decades of industry experience at TRC Companies, was provided to highlight the basics of electric generator protection principles. These principles are also applicable to the generators used in nuclear plants.

In November 2019, a guest speaker, who is a nuclear engineer from Duke Energy's Oconee nuclear station, came to visit our university to present the topic Nuclear Power Plant Systems. The topics covered were a brief overview of nuclear power, an overview of pressurized water reactor plant systems, primary system, nuclear reactor design and control, primary system components, secondary system, steam generation, main turbine/generator, condenser and feedwater, tertiary system design, and heat rejection.

Six field trips opportunity were provided to the NRC scholars during the Fall 2017 through Spring 2020 semesters. In Fall 2017, students and project personnel visited Oconee nuclear station where a Duke Energy engineer provided a detailed tour of the power plant operations. In Spring 2018, students visited Eaton Corp, a company with strong ties to the nuclear power industry. A tour of manufacturing assembly lines as well as company highlights were provided during this trip. As a result of this networking opportunity, two scholars received offers for summer internship at Eaton Corp and one scholar received a full-time employment offer after graduation. During the Fall 2018 and Spring 2019 semesters, NRC scholars toured two generation facilities operated by Duke Energy. The first one was Thorpe hydroelectric plant, visited in September 2018, and the second one was Oconee nuclear station, visited in February 2019. Two additional field trip opportunities were provided to NRC scholars in Fall 2019 and

Spring 2020 semesters. In Fall 2019, the scholars who were not participants in Fall 2018 visited the same Duke Energy hydroelectric generation facility mentioned above, and received a power plant tour from one of their engineers. During the Spring 2020 semester, students visited and toured the Eaton corporation facility located in Arden, NC. A project personnel chaperoned the scholarship recipients during this trip.

For all field trips, NRC scholars were asked to write reports highlighting their technical observations. The following is a reflection excerpt by one scholar after the tour of Oconee nuclear station:

> "The immense size and convolution of the operation of the plant is astounding. There is a certain pressure felt while standing in the control center. It is seemingly my own experience that tells me I am looking towards getting a job as an operator. It serves as a constant reminder that the more you understand the depth of your field, the less you really know and understand. For someone like me, interested in the electricity generation aspect of the plant, the nuclear aspect puzzled me in new ways. I am thankful that this opportunity was provided to the NRC scholars, and I hope that another adventure arises from this program before graduation in May of 2019".

IV-e. Progress and end of year meetings

All new scholarship recipients held meetings with the PI and discussed their progress throughout the program. In addition, their PBL course engagement options and professional development opportunities, such as summer internship as well as research options, were introduced. Each of these students also received individual advice for course registration and planning towards graduation. These students successfully maintained their GPA requirement during the NRC scholarship term.

At the end of each semester, all scholarship recipients met with the PI and/or a Co-PI. Reflection summaries of their scholarship experience for the semester were requested in written form. Per their statements, the participants were generally satisfied with the program and were able to concentrate on their course work more effectively with the financial assistance provided. This was also reflected in their overall GPA levels. All students maintained their GPA level, which were higher than what was required by their service agreement. In addition, summer internship and research engagement activities in the relevant fields were promoted and various options were discussed. During the Summer 2018 and 2019 terms, fourteen scholars engaged in twenty different summer professional development activities, fifteen of which was wither nuclear industry or academic research related. Various networking opportunities (e.g., college career fairs) were best suited for the summer engagement activities.

As of Spring 2019, the scholars were encouraged to participate in the professional development program activities at WCU. This program is called DegreePlus and it is specifically focused on developing transferable professional skills through extracurricular experiences, such as, leadership, teamwork, cultural responsiveness, and professionalism. The scholars' participation record was tracked, and they were required to provide a progress report during every meeting.

V. Evaluations and Results

The results provided in this section were based on the data collected until the end of Spring 2019 semester. The first evaluation activity was the surveys of award candidates and a sampling of other students recruited into the engineering program with electric power (EPE) and mechanical (ME) concentrations at WCU. These initial surveys were distributed in three different classrooms and had a total of 34 responders (mostly junior and some senior students) including the seven scholarship recipients in Spring 2018 semester. The results suggest that all NRC scholars agree that funding provided by NRC scholarship is important in their pursuit of their degree. The level of agreement with this question (i.e. "The funding provided by my NRC scholarship is important to my being able to pursue my degree") was the highest level among all other questions asked. Another interesting result showed that only 4 out of 7 seven scholars agreed that the NRC scholarship provided enough support for them to primarily focus on their degree without having a job. These two results combined revealed that the NRC scholarship is a fundamental support mechanism to the pursuit of their degree completion, but it may not be enough financial support for all participants. This assessment and findings align well with the socio-economic status of Western North Carolina region. Analyses of these survey results that are applicable to outreach and recruiting activities were published in the proceedings of ASEE annual conferences 2019[13] and 2020[14].

The second-stage survey (just before graduation of first cohort of NRC scholars) was conducted during the Spring 2019 semester in two different classrooms and included 42 participants (junior and mostly senior level engineering students). The agreement level on the question (answered only by NRC scholars) concerning the NRC scholarship's impact on being able to pursue their degree was similar to the initial survey results. All NRC scholars generally agree the funding provided by the NRC scholarship is important to his/her being able to pursue his/her degree. The survey result on a follow-on question showed that 5 out of 7 seven scholars agreed that the NRC scholarship provided enough support so that they can focus on their degree without having a job. This ratio was 4 out of 7 in the initial survey. Additional semesters of support with NRC scholarships can be a contributing factor to the improved results in this question. In another question, all students participating in the survey were asked if they would like to get better acquainted with other NRC scholars. This ratio was 12/34 (~35.3%) in the initial survey and 18/42 (~42.9%) in the final survey. This result may suggest that the scholarship program, between the time these surveys were administered, developed a positive (or at least non-declining) trend/impression among participants. Another survey question was about participants' excitement concerning a career based on the student's major in one of the engineering programs. The agreement rate in the initial survey (considering all participants) was 88.2%, while in the final survey the rate was 92.8%. Again, the trend was somewhat positive (or at least non-declining). An interesting result was observed when participants were asked if it would be a good addition to organize fun social activities for participating students in the scholarship program. First survey respondents had a rate of agreement of 61.8% and the final survey respondents had a rate of agreement of 59.5%. These results were relatively close and combined results revealed that fun social activities would be a good option to consider in terms of future planning. In terms of demographics of surveyed participants, the initial survey had 4 female and 28 male students, and the final survey had 4 female and 38 male students.

Secondly, WCU's Office of Institutional Planning and Effectiveness was contacted to collect the project's evaluation data including enrollment, retention, graduation and GPA levels for the engineering program, as well as our scholarship program. Some of the highlights are as follows (the scholarship program with first cohort started in Fall 2017).

All students in Electric Power Engineering and Mechanical Engineering (EPE-ME) programs:

1. Both Fall 2016 to 2018 (150 to 198) and Spring 2017 to 2019 (139 to 194) enrollment levels for all students in the engineering programs are increasing.
2. Retention level for all students from Fall 2016 to Fall 2017 semesters is 78% and from Fall 2017 to Fall 2018 semesters is 65%. The retention level is somewhat decreasing.
3. Number of graduates from EPE-ME programs is 8 in Spring 2017 (first graduating class), 2 in Fall 2017, 22 in Spring 2018, 3 in Fall 2018 and 25 in Spring 2019 semesters. The number of graduates from spring to spring and fall to fall semesters is increasing.
4. Average GPA for all students was flat 3.1 in Spring 2017 through Spring 2019 semesters.
5. In terms of student gender & ethnicity, in Spring 2018 there were 168 students of which 24 (14%) was ethnically diverse and 16 was female (10%). In Spring 2019 there were 194 students of which 24 (16.5%) was ethnically diverse and 22 reported female (11%).

Using the above as a baseline and comparing these data to NRC scholars.

1. Enrollment for NRC scholars was 3 in Fall 2017, 7 in Spring 2018 and Fall 2018, and 12 in Spring 2019 semesters. Since there was a limit with the scholarships we can award, it wouldn't be fair to make a comparison.
2. Retention level for NRC scholars is 100% to date. This is much better than overall trends within (EPE-ME) programs.
3. Number of graduates for NRC scholars in Spring 2019 was 4. Since the expected number for Spring 2019 was 4, we achieved 100% graduation rate. Eight students continued their study after Spring 2019; one was scheduled to graduate in Fall 2019, five were scheduled to graduate in Spring 2020 and two were scheduled to graduate in Spring 2020 semesters. Again, the graduation rate for NRC scholars were much better than the general student body.
4. Average GPA for all NRC scholars in Fall 2017 was 3.5, in Spring 2018 the GPA was 3.7, in Fall 2018 the GPA was 3.7 and in Spring 2019 was 3.6. These numbers are again much better than the average GPA for all other students in the program.
5. In terms of student gender & ethnicity for all NRC scholars, in Spring 2018 there were 7 students of which 1 (14%) was ethnically diverse and 2 reported female (28%). These numbers are either equal or better than the numbers for all EPE-ME programs.

In terms of placement in the nuclear-related workforce, 3 out of 4 scholars who graduated in Spring 2019 semester were placed in the electric utility industry applicable to nuclear generation. An interesting fact was that all three scholars received offers from the same companies where they completed their internships in the summer of 2018. One scholar, after months of efforts before and after graduation, completed several dozen applications to the relevant industry, but the outcome was not positive. This was the only scholar who was unable to find an internship in

the nuclear-related industry before graduation. However, this student is currently engaged full-time in the engineering workforce.

VI. Conclusions

In this paper, an implementation effort for nuclear-related workforce development was introduced. The implementation involved various activities including, but not limited to the following: PBL/research engagements; student advising and registration; progress and end of year follow-up meetings; professional seminars and field trips; and extracurricular courses. Evaluation results suggested that the scholar motivation, excitement, and engagement level throughout the program activities was either maintained or improved over the semesters. Although full evaluation results covering 2019-2020 academic were not fully compiled and the data available were limited, the summer engagement, especially the internships, were found to be the most rewarding activities that would result in employment in the relevant industry. Future work involves the study of a comprehensive analysis of implementation with a larger cohort.

Acknowledgements

The work presented herein was supported in part by U.S. Nuclear Regulatory Commission under the award numbers NRC-HQ-84-16-G-0030 and 31310018M0022.

Bibliography

1. U.S. Energy Information Administration (EIA) (2020) *Today in Energy*. Power Plant Operations Report.
2. Lederman, J (Feb. 17, 2021) *How one Texas storm exposed an energy grid unprepared for climate change*. NBC News.
3. American Physical Society (2008) *Readiness of the U.S. Nuclear Workforce for 21st Century Challenges*. Report from the APS Panel on Public Affairs Committee on Energy and Environment; Ridge, NY.
4. Crick, K. A., & Seipel, M. T., & Larson, L. M., & Shelley, M. (2020), Work in Progress: Building Community, Providing Scholarships, Developing Leaders: Recruiting and Retaining Underrepresented Students in Engineering and Computer Engineering Departments, ASEE Virtual Annual Conference, Conference Proceedings.
5. Jensen, P. H., & West, M., & Kellar, J. J., & Kellogg, S. D., & Karlin, J., & Degen, C. M. (2017), Culture and Attitude: A scholarship, mentoring and professional development program to increase the number of women graduating with engineering degrees. ASEE Annual Conference & Exposition, Conference Proceedings, Columbus, Ohio.
6. Tanner Hollis, Ghalib Shutayfi, Zachary Massey, William Benson and Bora Karayaka, (2018) Load Following of a Nuclear Power Plant, National Conference on Undergraduate Research, University of Central Oklahoma, Oklahoma City, OK.
7. T. Hollis, W. Benson, J. Knapp and H. Karayaka, (2019) Dispatching of a Scale Nuclear Power Plant using a Battery Storage, IEEE SoutheastCon Huntsville, AL.
8. David Inscoe, H. Bora Karayaka and Andrew Ritenour, (2020) Design and Implementation of a Load Following Emulator for Nuclear Power Generation, IEEE SoutheastCon Virtual Conference.
9. C. Reilly, T. Rayburn and P. Cruz, (2019) A Model to Accurately Predict Hydrogen Explosion Severity in Nuclear Power Stations, Appalachian Energy Summit 2019, Boone, NC.
10. Mary Emma Haywood, Kyle Monaghan, Nicholas Kropelnicki, Jarid Williams, Bora Karayaka and Nazmul Ahsan, (2020) Pumped Fluid Loop Thermal Management Design Proposal for NASA's Stirling Power Conversion System, National Conference on Undergraduate Research, Montana State University, Bozeman, Montana.

11. Caleb Lowe, Faisal Alosaimi, Muhammad Yousf, Jay Stanley, Jacob Bordelon and Bora Karayaka, (2020) Load Following Capability for Hybrid Nuclear and Solar Photovoltaic Power, National Conference on Undergraduate Research, Montana State University, Bozeman, Montana.
12. Caleb Lowe, Faisal Alosaimi, Muhammad Yousf, Jay Stanley, Jacob Bordelon, and H. Bora Karayaka, (2021) Load Following Capability for Hybrid Nuclear and Solar Photovoltaic Power Plants with an Energy Storage System, North American Power Symposium 2020.
13. Karayaka, H. B., Thompson, A. C. & Ferguson, C. W. (2019) Project Based Learning Program for Nuclear Workforce Development Phase I: Outreach, Recruiting, and Selection. ASEE Annual Conference & Exposition, Conference Proceedings, Tampa, Florida.
14. Karayaka, H. B., Ferguson, C. W. & Thompson, A. C. (2020) An Evaluation of Focused Outreach and Recruiting Efforts in a Nuclear-Related Workforce Development Program. ASEE Virtual Annual Conference, Conference Proceedings.