Board 412: Undergraduate Research and Innovation Experience in Cancer Diagnosis and Therapeutic Intervention

Dr. Nellone Eze Reid, New Jersey Institute of Technology

Dr. Nellone Reid has mentored several undergraduate students through his involvement in multiple grants and student organizations. As the former PI of Hampton University's I-Corps grant, Nellone managed LeanLaunch Pad, training 14 students in technology product development for the innovation grant. This led to students earning 3 venture capitalist investments and 4 consecutive innovation awards at the Advancing Minorities' Interest in Engineering (AMIE) design competition. Dr. Reid was the Director of Education for the Hampton-Brandeis Partnership for Research and Education in Materials grant, resulting in 90% student placement in doctoral (Ph.D. or MD) graduate programs. Dr. Reid continues to communicate with many of the 36-student cohort. As the co-director of the University of California (UC)-HBCU Pathways to Biophotonics and Biomedical Engineering, Dr. Reid assisted in placing three HBCU students in University of California graduate programs. In addition, five students gained experience through the program that led to admission to graduate programs at top universities such as Carnegie Mellon, Northeastern University, Rensselaer Polytechnic Institute, University of Chicago, and City College of New York. Dr. Reid also served as the American Institute of Chemical Engineers chapter advisor at Hampton University, earning grants to assist in multiple attending local and national conferences. Dr. Reid is the current direct and principal investigator of the NSF-funded NJIT Research Experience for Undergraduates – Undergraduate Research and Innovation Experience in Cancer Diagnosis and Therapeutic Intervention. Finally, Dr. Reid is passionate about volunteering, as shown by his involvement with NYCares and Alpha Phi Alpha Fraternity, Inc.

Undergraduate Research and Innovation Experience in Cancer Diagnosis and Therapeutic Intervention (Cancer Innovation REU)

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Abstract: There is a need for seamless and inexpensive approaches to detect and treat various types of cancer as diagnoses and deaths continue to increase in the United States (1.95 million new cases and 609,820 deaths in 2023), while cost of treatment also remains high ($1.16 trillion annually). The development of sensitive and accurate methods for detection of cancer in the early stages is essential, as ninety percent of all cancer deaths are caused by metastasis of original tumors. It is also necessary to have a diverse source of trained medical professionals and engineers, that will advance such emerging technologies. Organizations with above-average diversity in their teams report higher innovation successes. Unfortunately, there is a minimum uptick in minorities and women representation in the science, technology, engineering and mathematics (STEM) workforce from 1995 to 2017. The Undergraduate Research and Innovation Experience in Cancer Diagnosis and Therapeutic Intervention, is a summer research experience for undergraduates (REU) that includes research, education, and training activities for thirty students over three years, from underrepresented minority groups. Such groups include African Americans, LatinX, women, students with disabilities and first-generation college students. The goals of this project are to 1) engage undergraduate students to foster innovative research cancer diagnostics to therapeutic intervention; 2) cultivate multidisciplinary research among NJIT faculty; and 3) increase the participation in research by underrepresented minority groups, resulting in participants being co-authors on publications and presenters at scientific conferences. During the 10-week summer program, domestic student participants' main activities include carrying out individual cancer-related research projects in biomedical engineering, materials science and photonics. Students gain perspective on their career paths through weekly seminars with current doctoral candidates, medical professionals, entrepreneurs and engineers working in the biomedical and pharmaceutical fields. After their experience in the summer REU, a number of students were able to present their work at multiple conferences, including the American Institute of Chemical Engineers Annual Meeting and National Pre-health Conference. In addition, students were able to publish as a co-author with their summer mentor and advisor; become inductees to the National Academy of Inventors; and have continued on to post-undergraduate STEM programs. Through a series of surveys conducted by the Office of Institutional Effectiveness at New Jersey Institute of Technology, participants were largely satisfied with the program and would recommend it to other undergraduates. This REU will continue to strive to: 1) increase the number of undergraduates participating in research projects focused on cancer related research; 2) increase communication of bio-inspired science and engineering to undergraduate peers, faculty and general audience; and 3) diversify the supply of scientists and engineers contributing to American industries and economics as a whole.

I. Introduction

The American Cancer Society estimated that about 1.95 million new cancer cases and 609,820 deaths occurred in 2023 in the United States[1]. Annual health care costs for treating cancer are approximately $1.16 trillion[2]. The development of sensitive and accurate methods for detecting cancer in the early stages is essential, as ninety percent of all cancer deaths are caused by metastasis of original tumors[3]. The Undergraduate Research and Innovation Experience in Cancer Diagnosis and Therapeutic Intervention at the New Jersey Institute of Technology is as a new summer research experience for undergraduates that includes research, education, and training activities for ten students (per year) from underrepresented minority groups such as African Americans, LatinX, women, students with disabilities and first-generation college students. During an intensive 10-week summer program, the ten domestic student participants are introduced to research focused on cancer diagnosis, therapeutics, and mechanistic modeling. The main objectives of this REU site are to 1) increase interest in research on the synthesis, characterization, and applications of devices and methods for cancer detection and therapy among 80% of our cohort, composed primarily of underrepresented minority groups; 2) introduce scientific methods to the anticipated 30 (over 3 years) underrepresented undergraduate students early in their career, bridging academic knowledge acquired in class to innovative real-world research problems while developing confidence and skills in the communication of scientific research; 3) increase the ability of all students to develop solutions using advanced statistical and analytical techniques, simulations, or predictive modeling to understand and validate hypotheses; 4) diversify the supply of scientists and engineers to graduate schools, with a goal of 60% of our student participants entering research programs in advanced Science, Technology, Engineering, and Mathematics (STEM) degrees; and 5) improve all student participants' ethical reasoning and social awareness to develop successful engineers in an academic or professional environment.

II. Program Design

A. Targeted Student Participants

We strongly encourage the increase of scientific curiosity among individuals from underrepresented communities. NJIT has a largely diverse student population. Therefore, students from underrepresented groups in an REU site at NJIT, typically feel comfortable and welcomed in a student population of various backgrounds, while being exposed to a high level, state-of-the-art research, and facilities.

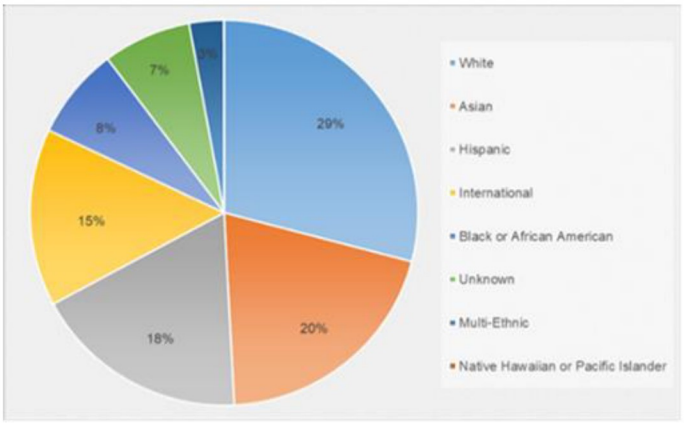

Fig. 1 New Jersey Institute of Technology racial-ethnic demographics

Recruitment of students is primarily focused on institutions with limited research opportunities, such as historically black colleges and universities (HBCUs) and community colleges. While HBCUs represent only 3% of higher education institutions, the top 10 Universities are noted for producing graduates that go on to pursue doctorates in STEM are all HBCUs[4]. In addition, females account for ~ 64 % of undergraduate enrollment at black universities[5]. Many of NJIT's undergraduate engineering students transfer to NJIT from a local community college (~25%). We have attempted to leverage our relationship with institutions, such as Bergen Community College, to recruit high-quality students. We will also encourage the involvement of students with disabilities. Studies show that roughly 33% of people without disabilities hold a bachelor's degree or higher, compared to only 14% for their counterparts with disabilities [6]. However, students with and without disabilities express interest in STEM majors at the same rates [7, 8]. Through recruitment from multiple HBCUs and community colleges, this REU seeks to: 1) increase the number of underrepresented undergraduates participating in research projects focused on cancer diagnosis, therapeutics, and mechanistic models; 2) increase communication of bio-inspired science and engineering

to a diverse audience; 3) diversify the supply of scientists and engineers contributing to American industries and economics as a whole. We expected at least 6 out of the 10 undergraduate students enrolled in our REU site to come from institutions outside NJIT and at least 60% from institutions with limited research opportunities. We will also strive to achieve or exceed the goal of recruiting at least 80% of the students from underrepresented groups, with 60% being women. Table 1 shows the self-identified demographics of the 2022 and 2023 cohort of scholars that participated in the REU. The data confirms we were able to serve a population that consisted of students that were – 73% from institutions outside of NJIT, 94% from underrepresented groups, and 78% women. In addition, we accepted one student with a disability that was extremely successful in the program and moved on to pursue their PhD in Biomathematics at Florida State University.

During the 10-week program, students are housed in dormitories on campus and provided with a competitive stipend ($600/week), meal ($100/week), and travel support ($1000). It is worth noting that the research mentors will each receive $1000 in supply money for the project. Students that participated in the first two years of the REU include:

- Yorquiria Maldonado (Chemical Engineering, New Jersey Institute of Technology)
- Stella Makuza (Biology/Pre-Med, North Carolina A&T University)
- Debbie-Ann Spence (Biology, New Jersey Institute of Technology)
- Halexandra Alvarenga (Chemical Engineering, California Baptist University)
- Noshin Siddiq (Chemical and Biomedical Engineering, New York University)
- Anne Nong (Chemical Engineering, Rowan University)
- Olivia Joy Dyke (Biomedical Engineering, California Baptist University)
- Luster Harris (Chemistry, Alcorn State University)
- Raylynn Thompson (Biology/Pre-Med and Biochemistry, Alcorn State University)
- Ricardo Inoa (Biology/Pre-Med, New Jersey Institute of Technology)
- Resty Mercado (Biomedical Engineering, Rowan University)
- Ricardo Otake (Chemical Engineering, Rowan University)
- Edem Ammamoo (Alcorn State University)
- Kaylie Green (Bioengineering/Applied Mathematics, Washington State University)
- Sofia Ruiz (Chemical Engineering, Lehigh University)
- Riya Patel (Biomolecular Science, New York University)
- Elizabeth Hervias (Chemical Engineering, New Jersey Institute of Technology)
- Maryom Rahman (Chemical Engineering, New Jersey Institute of Technology)
- Amina Anowara (Chemical and Biomedical Engineering, Princeton University)

Total	19
Female	14
Disabled	1
Black/African American	4
Hispanic	6
Native American	1
Asian/Pacific Island	6
White	3
Other	0

Table 1: Self-identified demographics of students participating in the Undergraduate Research and Innovation Experience in Cancer Diagnosis and Therapeutic Intervention (Cancer Innovation REU)

B. Mentor Pool

The research projects performed by the undergraduate students during the summer REU will be within the areas of diagnosis, therapy, and mechanistic modeling of cancer systems. To further this intellectual curiosity and the innovation spirit, the chosen faculty members are renowned, including multiple NSF awardees (2 NSF Career Award winners). The faculty members have a diverse intellectual focus in cancer, from diagnostic devices, machine learning, and mechanism to therapeutic interventions. The cohort of faculty mentors introduce students to dynamic research in physics and biochemistry and chemical, electrical, and materials engineering related to the advancement of cancer detection and treatment. Each

student is paired with at least one research mentor for ten weeks during the summer. As the primary mentor, a faculty member or Ph.D. research scientist will guide each student project, supported by another graduate student co-mentor. The involvement of graduate student co-mentors is essential for enhancing the REU student experience with more opportunities for abundant mentor-student interactions and hands-on training during the on-campus 10-week-long REU program. The program will lead to research and innovation at the New Jersey Institute of Technology (NJIT) by 1) engaging undergraduate students to foster innovative research cancer diagnostics to therapeutic intervention, 2) cultivating multidisciplinary research among NJIT faculty, and expanding to collaborate with multiple universities using the undergraduate students as a bridge and finally 3) increasing the participation in research by underrepresented minority groups, resulting in participants being co-authors on publications and presenters at scientific conferences.

Example projects offered to potential participants are listed below. Each project shows a mentor, type of project, brief description, the role of undergraduate students, and expected outcomes. The roles of the student participant can be adjusted to fit the level and background of the participants.

Example Project #1: Diagnosis of heart cancer by using nanomaterials
Primary Mentor: Lin Dong
Type of Project: Materials and Biomedical Engineering
Project Description: Heart cancer results from a heart tumor or another cancer that spreads to the heart. Heart failure is a vital sign of heart cancer; however, most patients cannot identify or properly self-assess the symptoms when they arise. This project aims to develop a new heart monitoring strategy using a nanomaterial-based sensing platform to effectively diagnose and timely intervention for heart cancers. We will design and fabricate new nanomaterials and measure heart signals to perform decision-making and real-time optimal control in heart cancer studies.
Role of Student Participant: The proposed project will be carried out in Dr. Dong's laboratory, and it will provide new multidisciplinary research opportunities for diverse students. Students participating in this REU program will be provided mentoring, training, learning, interdisciplinary teamwork opportunities, and hands-on practical experiences in nanomaterials fabrication, sensing technology, and system integration approach.
Expected Outcomes: The expected outcomes of this research are to (1) design advanced nanomaterials to measure heart signals; (2) extract physiological insights of the sensing data for assessment of heart status as an intervention tool for heart cancers. The scientific outcomes of this research will be a new sensing platform that is potentially revolutionizing cardiac cancer diagnosis solutions. Participants will learn knowledge of engineering fundamentals as they apply to materials science and biomedical engineering. Diverse students will involve in multidisciplinary research training and learning through this REU program.

Example Project #2: "ASSURED" point-of-care screening tool for rapid detection of cancer
Primary Mentor: Sagnik Basuray
Type of Project: Biosensors
Project Description: The two significant limitations of current analytical/diagnostic systems are: 1) Sensitivity or the species of interest are too low in the measured sample, thus leading to false-negative(s) 2) Selectivity or the sample may contain species of interest intermixed with many similar species, thus leading to false positives(s). The design must facilitate rapid analysis for Point-Of-Care (POC) diagnostic devices without using expensive or bulky equipment. The project aims to investigate a new POC electrochemical platform that combines shear force with a nanoporous and capacitive electrode. It meets the ASSURED criteria set by World Health Organization for POC diagnosis. Here the platform detects cancer biomarkers. The proposed research will integrate technologies for 1) a flow-through, nanoporous and capacitive electrode, 2) electrochemical sensor capable of label-free, multiplexed, rapid, portable, sensitive, and selective detection; and 3) integrates multiple electrochemical sensing techniques in one chip.
Role of Student Participant: The student participating in this research will rapidly develop and optimize the chip to detect breast cancer biomarkers. This includes the proteins p53, tumor suppression protein, human epidermal growth factor receptor 2 (HER2), breast cancer type 1 susceptibility proteins (BRCA1), and interleukin 6 (IL-6). The graduate student will train the undergraduate student to run devices to develop preliminary detection limits (LOD's) for p53 and HER2. The best LODs are 53 ng/L using enzyme-based amperometry for p53 70, 37 pg/L using square wave stripping voltammetry (SWV) for HER2. The

undergraduate student will also investigate p53 and HER2 diagnosis selectivity by spiking the blood plasma with other proteins, DNA, and biomaterials like lysed ecoli cells. The other biomarkers for breast cancer and other cancers will also be similarly explored in successive years.
Expected Outcomes: The primary research outcome will be to validate the selectivity and sensitivity of the device. The student researcher will develop a calibration plot and get the LOD. The student is expected to show the effect of the interference matrix on the LOD. The undergraduate student will be able to integrate a chip, run a chip and analyze the results from the chip by the end of the REU project. During the research, the undergraduate student will get valuable insights into statistical analysis like p-test, student t-test, electrochemical spectroscopy like cyclic voltammetry, electrochemical impedance spectroscopy, and handling sensitive biological samples. We expect the undergraduate student to show their findings in an appropriate research conference like ACS, BMES, or AIChE.

Example Project #3: Rational design of EGFr binding peptides
Primary Mentor: Vivek Kumar
Type of Project: Computational peptide design, in vitro and in vivo efficacy models
Project Description: Non-target side effects of systemic therapeutics have provided the impetus for developing next-generation carriers for in situ drug delivery. We have developed a (self-assembling) peptide platform tailorable with receptor binding domains – e.g., EGF-receptor highly expressed in breast and ovarian cancers. This consequent death can be addressed by novel biomaterials-based drugs that address 3 vital aspects: i) de novo design and targeting of promiscuous receptors, ii) in vitro cytocompatibility and receptor binding, iii) in vivo localization and targeting of receptor-positive cells. Here we seek to computationally develop EGF-receptor binding peptides and assay theirs in vitro and Vivo efficacy in abrogating proliferative malignant tissue disease. The goals are to i) Design an EGFr binding (self-assembling) peptide; ii) Development of peptide vehicle to carry anti-neoplastic payloads; iii) Evaluation of peptide receptor binding in vitro and in vivo.
Role of Student Participant: Students participating in this REU as a mentee of Dr. Kumar will be responsible for the initial design, fabrication, and characterization of peptides. Students will utilize a computational peptide modeling (GROMACS+Rosetta) to design EGFr binding peptides; solid-phase peptide synthesis to make peptides and characterize them (LC/MS, circular dichroism, FTIR, AFM, SEM); evaluate in vitro binding (SPR and fluorescent-tagged peptide with EGFr+ cells) and in vivo (time and funds permitting).
Expected Outcomes: The targeted outcome will be to develop a novel approach for the targeting of EGFr+ cancers, their potential for diagnosis and treatment. The results will provide critical data to prove the feasibility of our approach and allow further evaluation of the abilities of rational peptide design for the treatment of cancer. In addition, participants will learn basic methods of computational design, synthesis, characterization, as performed by UG in the lab regularly.

Example Project #4: Protein corona formation and aggregation studies on targeted drug delivery nanoparticles for triple-negative breast cancer
Primary Mentor: Kathleen McEnnis
Type of Project: Materials Engineering and Drug Delivery
Project Description: A significant hurdle for drug delivery nanoparticles is the circulation of the nanoparticles. Many drug delivery nanoparticles fail at this step and are quickly shunted by the immune system to the liver [9,10, 11, 12]. One theory for removing particles is that the formation of a protein corona on the particle signals for its removal[13]. Therefore, accurately measuring the protein corona of nanoparticles in blood plasma is crucial to understanding how the particle will behave *in vivo*. This project will synthesize PLGA nanoparticles with a targeting ligand (an antibody for EGFR, a receptor overexpressed in triple-negative breast cancer) and PEG ligands. Particles with different ratios of these ligands will be synthesized. The particles will be analyzed in blood plasma using nanoparticle tracking analysis (NTA) to determine the size of the complex and soft protein corona on the particles and the aggregation behavior over a 24-hour

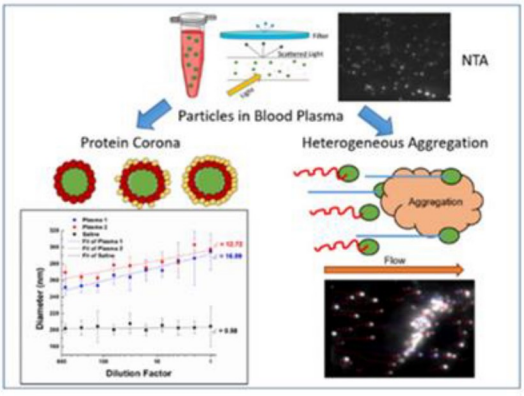

Fig. 2 Nanoparticle tracking analysis of polymer nanoparticles in blood plasma

incubation time in blood plasma. Analysis of the particles with different ligand expressions will determine the optimal ligands for particle circulation in blood.
Role of Student Participant: Students participating in this REU as a mentee of Dr. McEnnis will be responsible for the NTA measurements in saline and blood plasma to determine particle size, centrifugation and washing steps of the particles to determine hard and soft corona size, and viscosity measurements of the blood plasma for accurate size analysis. The student will assist with particle synthesis and surface chemistry modifications. Additionally, the student will assist in a study observing the particles in plasma over 24 hours and will analyze the resulting videos for the presence of multicomponent aggregates.
Expected Outcomes: The outcome will determine the optimal ligand presentation for enhanced circulation time of targeted drug delivery nanoparticles for triple-negative breast cancer. The results will be coupled with corresponding cellular uptake data of the identical particles with triple-negative breast cancer cells and healthy breast tissue. Together these results will provide preliminary data of the most promising nanoparticle design to test in future in vivo studies. In addition, student participants will learn particle characterization techniques and polymer-drug delivery synthesis and modification basics.

Example Project #5: Kinetic Modeling of Lipid Metabolism of Breast Cancer Cells in Electrode Equipped 3- D Printed Microfluidic Device
Primary Mentor: Nellone Reid
Type of Project: Materials Engineering and Biophotonics
Project Description: Due to high surface area to volume ratio, low cost of production, and ease of complex fluid handling, microfluidics provide a potential pathway to cancer diagnosis[14]. Quantitative analysis of cancer cell metabolic kinetics is of great importance in characterizing cancer cell behavior and unraveling the role of cell metabolism in cancer progression and transformation. The goals of this research are to 1) study and compare the effects of an EMF through imaging of non-deuterated and deuterated lipids in healthy and cancer cells on a 3-D printed microfluidic device with planar electrodes; 2) develop quantitative models that accurately describe the effect of EMF on lipid metabolism of cancer cells.

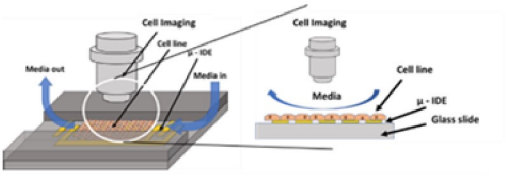

Fig. 3 Imaging of cell line on electrode-equipped microfluidic device

Role of Student Participant: Students participating will be responsible for the initial fabrication and characterization of microfluidic devices. Students will utilize a stereolithography 3-D printer, 3-D optical profilometer, and optical microscopes for fabrication, characterization, and visualization of microfluidic devices, respectively. Specifically, students will 1) fabricate series of electrode-equipped, 3-D printed microfluidic devices; 2) perform characterization and biocompatibility studies; and if time permits, 3) image healthy and breast cancer cells in order to establish proof of concept.
Expected Outcomes: The targeted outcome will be to develop a novel approach to diagnosing and treating cancer cells using non-invasive methods. The results will provide critical data to prove the feasibility of our approach and allow further evaluation of the abilities of non-linear microscopy and the effectiveness of electromagnetic fields on cancer cells. In addition, participants will learn basic methods of fabrication and characterization of 3-D printed microfluidic devices for biophotonic studies.

C. Seminars and Workshops

The main objective of this REU is to increase the interest in research for cancer detection and therapy and develop minority undergraduate students early in their academic careers in order to diversify the pool of scientists and engineers for graduate school and the future workforce. We accomplish this through our lecture series, engineering ethics training, and collaborating with existing REUs at NJIT (i.e., Undergraduate Research Innovation and McNair Achievement programs) that offer additional professional training/workshops. Such workshops include:

1. Personal Statement
2. Funding Graduate School
3. GRE Preparation
4. Resume Writing and Interview Skills
5. Effective Poster and Oral Presentation

Unique to the Cancer Innovation REU are the weekly lecture series that feature professionals, professors and graduate students that provide students with perspective on potential career paths. Speakers are selected based on their ability to share experiences as a graduate/medical student, pharmaceutical engineer, and in innovation/start-up businesses. Speakers from the 2022 and 2023 program include:

- Baseemah Rucker – PhD Candidate, City College of New York
- Roli Kargupta – Industrial Scientist, Merck Pharmaceuticals
- Cheryl Bodnar – Associate Professor, Rowan University/Entrepreneurial Mindset
- Antonia Francis Oladipo – Maternal-Fetal Medicine and Surgery
- Susan Okrah – PhD Candidate, University of Chicago
- Anne Okrah – Phd Candidate, Northeastern University
- Cesar Bandera – Leir Chair and Associate Professor of Entrepreneurship, NJIT/ Funding Research and Start-Ups
- David E. Jones – Chief Diversity Officer, NJIT/Imposter Syndrome
- William Lutz – Director of Commercialization, NJIT
- Don Sebastian – Professor, Chemical and Materials Engineering, NJIT/Growth of Innovation in Newark, NJ
- Richard Cimino – Senior University Lecturer, Chemical and Materials Engineering, NJIT/Engineering Ethics
- Selim Rachidi – Industrial Scientist, Novartis Pharmaceuticals

D. Social and Cultural Activities

The benefits of proper work-life balance are well documented in peer-reviewed publications for more than 30 years[15]. They include benefits to the individual, their family but also to the employers themselves, in terms of increased productivity, worker retention, improved recruitment capabilities and increased loyalty, among others[16]. Students in the Cancer Innovation REU program will have access to the large number of activities a major city has to offer.

Fig. 4 Cancer Innovation REU students participating in social

Fig. 4 Cancer Innovation REU students participating in social activities – A) Hamilton on Broadway and B) site-seeing the Freedom Tower, Brooklyn Bridge and Brooklyn Bridge Park

NJIT is located ~10 miles away from New York City, ~40 miles away from the New Jersey shore, and less than 2 hours from Philadelphia. Students will be able to take advantage of the abundance of summer activities and festivals hosted by the tri-state area, including but not limited to Independence, Puerto Rican, and Dominican Day parades, as well as the AfroFestival in Brooklyn and Broad Street Festival in Philadelphia. The first and last week of our program will involve a welcome and farewell dinner, respectively. In addition, to cultivate a better student-to-student interaction, the students can participate in social activities organized by the URI program. Social activities are voluntary and affordable, so each REU student willing to participate can easily do so. Fig. 4 showcases students attending Hamilton the Broadway Musical (A) and walking across the Brooklyn Bridge while site-seeing New York City (B). Students greatly appreciated the experience, as some had never visited New York City. Student-to-student interaction during social and cultural activities allow for the students to enjoy their summer outside of research and promote a healthy work life balance early in their careers. In addition, students are able to network with one another, building professional bonds that will last beyond their summer experience. Some pictures are

posted on the REU website (https://web.njit.edu/~ner3/index.html), making the experience more attractive for prospective applicants.

E. Biweekly and Symposium Presentations

A significant goal of our REU is to engage with undergraduate students from underrepresented groups, resulting in skill sets that will allow them to be presenters at scientific conferences. The mentors will engage with their students to ensure quality presentations by providing templates and training sessions. The International Undergraduate Summer Research Symposium, organized by the NJIT URI program, provides an opportunity for our participants to present to a diverse audience. All students are required to present their results at the Symposium. Preparation for the final presentations occurs throughout the program. Biweekly, each student provides a short, progress report (~3 minutes to simulate the final URI presentations) to other students and mentors. These presentations allow the mentors to assess the students' progress, and the students practice their presentation skills early and frequently in the program. Based on the presentations, mentors give the students feedback regarding their understanding of the specific project and presenting style. This also serves as an opportunity for the PI/coPI to assess the effectiveness of the project early on in the program. Discussions with mentors will occur if problems arise or adjustments are needed. Cancer Innovation REU students have received an honorable mention for the Dr. James F. Stevenson Innovation Award in Material Science and Engineering for their presentation at the URI Symposium. While, two were inducted in the National Academy of Inventors at NJIT. Experience preparing and presenting at the symposium was beneficial to the students, as eight went on to present at additional national conferences.

III. Program Highlights

A. Research Environment

One of the primary objectives of the program is to encourage participation by students from institutions with limited research infrastructure. Our students benefit from the following unique facilities: NJIT Nanofabrication Center, Makerspace, Add-Lab, and Otto H. York Center for Environmental Engineering and Science. The Nanofabrication Center allows faculty and students to test, validate and translate innovative medical devices and biosensor technologies to improve diagnosis and treatment of acute diseases and advance detection and remediation of pollutants. Researchers can print their designs on silicon or glass plates, fabricate, and test them. Because the parts they are making are micro-and nanoscale, the rooms are free of potentially contaminating particles larger than a micron. The Otto H. York Center for Environmental Engineering and Science offers core research facilities as a resource for many interdisciplinary research programs and initiatives. It has a diverse set of equipment, with research projects in nanotechnology, drug-delivery systems, particle engineering, microfluidics, membrane science, environmental science and engineering,

Peptide synthesizer	Rheometer	Microfluidic Chip
Circular Dichroism	Fourier Transform Infrared Resonance Spectroscopy	Cell Culture
Convolution Neural Network	Python	Bright-Field Imaging
Pharmacokinetic Models	Mass Spectrometer	Integrated Development Environment
Electrospinning	Scanning Electron Microscope	Electromagnetic Fields
Live/Dead Assays	Piezoelectric Materials	Bioreactor Design
Stereolithography (3D-Printing)	High Performance Liquid Chromatography	Fusion 360 computer aided design (CAD)
Electrochemistry Impedance Spectroscopy	Nanoparticle Tracking Analysis	Nuclear Magnetic Resonance

Table 3: List of technical equipment, devices, software and methodologies in which students received training in during the Cancer Innovation REU

and biomedical engineering. The NJIT Makerspace is a rapid prototyping and collaboration facility where engineers, architects, designers, and scientists can create and test ideas, put theory into practice, and turn ideas into reality. This 21st-century prototyping, manufacturing, and collaborative space allow students, faculty, and industry partners to build physical systems in a functional and inspirational environment. The 10,000 square-foot Makerspace is the largest of its kind in New Jersey and houses the industrial-grade tools and technologies. The Makerspace offers devices for 3D printing, additive manufacturing, material cutting and shaping, metrology, visualization, computing, emulation, and simulation. Specifically, students in the REU have been trained in the instruments and methodologies found in table 3.

B. Program Deliverables

As mentioned, each student in the REU is required to present their research at the International Undergraduate Research Institute Symposium at the end of the 10-week program. This symposium includes over 100+ students participating in REU's at NJIT. In addition, students are required to submit a number of technical deliverables to the PI of the Cancer Innovation REU, including a 1) Biographical Sketch; 2) Personal Statement; 3) Resume; 4) Literature Review; 5) Abstract; 6) Poster (optional); 7) PowerPoint Presentation; and 8) Research Paper. The deliverables are consolidated into one document that also includes an overview of the program and feedback from the PI and mentor, on each students' performance. The document is sent to individual student recommenders and their home institution department chair, with other names redacted from the document. This provides the recommenders and departments chairs insight to the impact the program had on their students, as well as the students' performance. Below are the topics each student worked on during the program.

- Effect of Molecular Weight on the Curing of PEGDA Hydrogels, Yorquiria Maldonado (Student), Dr. Amir Miri (Mentor)
- Detection of PFOA through an Electrochemical EIS Microfluidics Platform named ESSENCE, Stella Makuza (Student), Dr. Nellone Reid (Mentor)
- Using Convolutional Neural Networks to Classify and Predict Pneumonia in Pediatric Chest X-Ray Images, Debbie-Ann Spence (Student), Dr. Joshua Young (Mentor)
- Point-Of-Care Clinical Device to Screen Microcystin-LR, Anatoxin-a, and Cylindrospermopsin Found In Freshwater, Halexandra Alvarenga (Student), Dr. Sagnik Basuray (Mentor)
- Investigating platinum nanoparticles for cancer treatment, Noshin Siddiq (Student), Dr. Kathleen McEnnis (Mentor)
- Design and Preliminary Assessment of a Self-Assembling Peptide Hydrogel for Drug Delivery, Anne Nong (Student), Dr. Vivek Kumar (Mentor)
- Electrospun Piezoelectric Nanofiber Device for Cancer Detection using P(VDF-TrFE) fibers via Wearable Patch, Olivia Joy Dyke (Student), Dr. Lin Dong (Mentor)
- Estimation of dermal absorption of chemical agents using physiologically-based pharmacokinetic models, Luster Harris (Student), Dr. Laurent Simon (Mentor)
- 3D Bioprinting of Soft Tissue Sarcoma Spheroids-Laden GelMA for Tumor Modeling, Raylynn Thompson (Student), Dr. Amir Miri (Mentor)
- Exposure Guidelines for Dermal Diffusion of Chemical Warfare Agents, Ricardo Inoa (Student), Dr. Laurent Simon (Mentor)
- Manipulation of Burst Pressure within FRESH vascularization, Resty Mercado (Student), Dr. Amir Miri (Mentor)
- Effects of EMFs on PME and T47D Cells, Ricardo Otake (Student), Dr. Nellone Reid (Mentor)
- Use of Machine Learning Models to Predict Breast Cancer, Edem Ammamoo (Student), Dr. Joshua Young (Mentor)
- Targeted Drug Delivery: Investigating Protein Corona Behavior, Kaylie Green (Student), Dr. Kathleen McEnnis (Mentor)
- Utilizing Anticancer Peptides to Combat Triple Negative Breast Cancer, Sofia Ruiz (Student), Dr. Vivek Kumar (Mentor)
- Integrated Electronics and Pulsed Electric Generators to Mimic Tumor Cell Response to Electrical Stimulations, Riya Patel (Student), Dr. Amir Miri (Mentor)

- Electrospun PVDF Nanofibers for Early Cancer Detection via Acoustic Wave Sensing, Elizabeth Hervias (Student), Dr. Lin Dong(Mentor)
- Manufacturing a State-of-the-Art Selector Valve for a Miniature Peptide Synthesizer, Maryom Rahman (Student), Dr. Vivek Kumar (Mentor)
- Porous Hydrogels As A Transducer Material In Microfluidic Electrochemical Cells, Amina Anowara (Student), Dr. Sagnik Basuray (Mentor)

C. Broader Impacts

The broader impacts of this project are multifaceted. The research may lead to patents for low-cost, miniaturized devices to diagnosis, treat and monitor cancer progression or transformation. In third world countries, where resources can be scarce, such devices can save countless lives by allowing early detection of cancer prior to the metastasis of the original tumor.

An increase in the supply of diverse students in the engineering workforce is a strong desire and passion of the grant's PI and Co-PI at NJIT. Companies with above-average diversity in their management teams report higher innovation revenues by 19 percentage points than those with below-average leadership diversity[17]. In addition, earnings before interest and taxes (EBIT) margins are 9 percentage points higher than those of companies with below-average diversity on their management teams [xv]. However, as shown in figure 5[18], there is a minimum uptick in minorities and women represent at a start ion in the Engineering workforce from 2003 to 2017. Similarly, the percentage of black and indigenous people of color (BIPOC) men and all women obtaining undergraduate and graduate degrees has increased minimally from 2011 to 2021, compared to all Engineering degrees across the same time. The number of BIPOC men obtaining a graduate degree in Engineering has decreased from 9.3% to 6.7% from 2011 to 2021 (table 4[19]). A primary goal of this project is to diversify the supply of scientists and engineers contributing to American industries and economics as a whole.

Year		2011	2021
Undergraduates	Total Awards	77,802	134,694
	Women	18.9%	24.1%
	BIPOC Men	14.7%	16.2%
Graduate	Total Awards	47,581	58,985
	Women	22.1%	27.3%
	BIPOC Men	9.3%	6.7%

Table 4: Percentage of all women. and Black/Indigenous People of Color (BIPOC) men engineering undergraduate and graduate degree awardees compared to total awardees

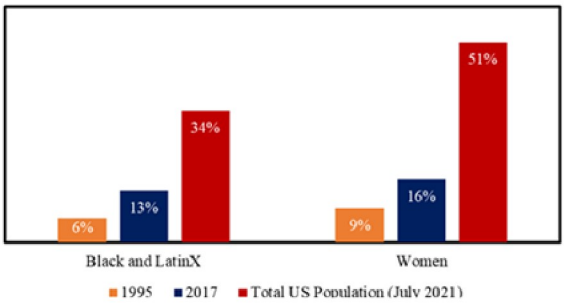

Fig. 5 Demographic composition of the engineering workforce (%) from 1995 through 2017

By emphasizing the recruitment of students from underrepresented populations, specifically HBCUs, and from community colleges, this program ultimately seeks to increase the numbers of these students pursuing graduate studies; all groups are underrepresented in graduate enrollments. By focusing on cancer diagnosis, therapeutics, and mechanistic modeling, this program seeks to increase the number of students entering the workforce with skills in this area. We will target undergraduate students from such underrepresented minority groups in order to increase scientific curiosity among individuals from underrepresented communities, including African Americans, LatinX and women students. This invaluable experience will strengthen their academic networks, increase their attractiveness for graduate research programs and provide them with future career opportunities. Although many have yet to graduate, students that participated in this

REU have already presented their work at the American Institute of Chemical Engineers (AIChE), National Pre-Health, and Biomedical Engineering Society national conferences; secured internships and employment with the National Aeronautics and Space Administration (NASA), Olivia Fresenius Medical Care/Renal Research Institute, BioSMART NSF REU, and Curvebeam AI start-up; and acceptance to PhD and MD programs at Florida State University, Logan University and Penn State University. In addition, one student was able to publish with their REU mentor and graduate student – "Influence of particle z-potential and experimental procedure on protein corona formation and multicomponent aggregation."[20]

IV. Program Assessment

A. Assessment Plan

The Office of Institutional Effectiveness (OEI) assess the program using pre-, mid-and post-site surveys. The surveys include both Likert-type questionnaire items and open-ended questions. Specifically, the pre-site survey are implemented to the student participants before the beginning of the program. This survey aims to assess participants' abilities and backgrounds related to the program objectives, learn more about their expectations from the program, and focus on their needs and preferences during the program's implementation. For example, the survey will include items that assess participants' awareness of advances in the field of the cancer treatment area, expectations of what they will achieve by the end of the program, and whether they have experience working in a lab environment and using lab equipment. The post-site survey are implemented to the participants at the end of the program. The goal of the post-site survey is to measure to what extent the student participants found the program relevant and engaging, whether they acquired new knowledge or skills from the program, and whether the program met the target objectives and outcomes. For example, the survey will include items that will inquire whether they will pursue a graduate degree in a STEM-related area, will assess whether their participation in the program improved their understanding of cancer treatment and their research and communication skills, and examines the effectiveness of the mentorship during the program. At the end of the program, OIE analyzes the survey

Objective	Activity	Data Collection
Increase interest in cancer research.	- Weekly seminars - Visiting facilities and laboratories related to the REU	- REU evaluations, interviews, and surveys - Research results
Introduce scientific methods while developing confidence and skills in the communication of scientific research.	- Weekly seminars - Completion of individual research projects -	- REU evaluations, interviews, and surveys - Research results - Final project and poster presentation
Increase the ability of all students to develop solutions with the use of advanced statistical and analytical techniques	- Feedback on research memos and final project report - Feedback on final presentations	- REU evaluations, interviews, and surveys - Final project report and poster presentation - Post-REU conference presentations
Diversify the supply of scientists and engineers to graduate schools	- Learning about graduate school preparation and selection. - Interaction with graduate students - Frequent meeting and working in research labs	- REU evaluations and surveys - Surveys of participant's home institution
Improve ethical reasoning and social awareness of all student participants	- Attend and actively participate in engineering ethics seminars	- REU evaluations and surveys - Feedback from seminar host.

Table 5: Summary of Site objectives, activities, and data collection for Cancer Innovation REU

data using appropriate statistical methods, write a report including the findings from the data analysis, and share it with the stakeholder. In addition, the report also includes relevant recommendations to improve the effectiveness of the program. The report also addresses the project's ability or inability to obtain 1) at least 6 out of the 10 undergraduate students enrolled from institutions outside NJIT; 2) at least 60% from institutions with limited research opportunities; and 3) at least 80% of the students from underrepresented groups, with 60% being women.

B. Cancer Innovation REU 2022

The pre-site survey done by pen and paper received responses from 6 students while the post-site survey and the advisor/mentor survey conducted online received responses from 8 students and 14 participants respectively. At the outset of the program, one student out of the six expressed an interest in pursuing graduate studies in Cancer treatment field or a related program while the rest neither agreed or disagreed, and two expressed an interest in graduate students in a non-Cancer treatment field. In terms of participation benefits, 67% (n=6) of the participants stated that the summer program helped them in developing research skills in the cancer treatment field and understanding Engineering Ethics. Out of the nine participants only one disagreed with the former and two with the latter. Application process, Feedback received on short write-ups and on the final report and Individual research projects were elements of the program with which all participants were moderately to extremely satisfied. Few participants ($\geq$3) were slightly satisfied with the meetings with Advisor and Program Director (n=1), Seminars and colloquiums on public speaking and academic writing (n=3), Seminars on Research and Intellectual Properties (n=1) and Research projects (n=1) while the rest were moderately to extremely satisfied.

Overall, 50% (n=4) of the participants reported that they were very satisfied with the program while 13% (n=1) each were slightly and extremely satisfied and 26% (n=2) were moderately satisfied. Six students (n=6) out of the eight would recommend the program to other undergraduate students wishing to pursue graduate studies in cancer treatment or a related area while two (n=2) would not. In both pre- and post-site surveys, all of the participants agreed they were interested in pursuing graduate studies if they were financially supported. After taking part in the program, the strength of agreement with pursuing graduate studies when financially supported inclined from 3 to 8 participants, suggesting an increased level of interest in financially-supported graduate studies for the majority of participants. Second, the number of participants who were not interested in pursuing a graduate degree if not financially supported increased 50% from 1 out of 6 students to 6 out of 9 students. Lastly, six students (n=6) out of the eight would recommend the program to other undergraduate students wishing to pursue graduate studies in cancer treatment or a related area while two (n=2) would not.

C. Cancer Innovation REU 2023

The pre-site survey received responses from 10 students, while the post-site survey and the advisor/mentor survey conducted online received responses from 8 students and 13 participants, respectively. After the summer REU program, only two students remained "Agree" that they are interested in pursuing graduate studies even if they are not financially supported. All other students are either "Disagree" or "Strongly Disagree". Both in the pre-and post-workshop surveys, most students suggested that they either "Agree" or "Strongly Agree" that they are interested in pursuing graduate studies only if they are financially supported. Before the REU, half of the students (n=5) expressed an interest in pursuing graduate studies in the Cancer treatment field or a related program, while the rest neither agreed nor disagreed. In addition, three students expressed an interest in graduate studies in a non-cancer treatment field. After the workshop, none of the students "Agree" or "Strongly Agree" that they plan to pursue a graduate degree in a field that is not related to Cancer treatment.

In terms of participation benefits all of the participants reported that participation in the program had improved their understanding and awareness of advances in cancer treatment and communication skills.

All participants stated that the summer program helped them develop research skills in the cancer treatment field. In addition, 75% (n=6) of the participants reported they “Agree” or “Strongly Agree’ that their participation in the REU program improved their understanding of Engineering Ethics. All of the participants were satisfied with the effectiveness of their co-mentor(s), and seven out of the eight participants were satisfied with the effectiveness of the mentor. Project selection, Individual research projects, Living accommodation, and Research projects were elements of the program with which all participants were very to extremely satisfied. All participants were moderately to extremely satisfied with the Application process and feedback received on short write-ups and final report.

Overall, 63% (n=5) of the participants reported being very satisfied with the program, while 38% (n=3) were extremely satisfied. All participants would recommend the program to other undergraduate students wishing to pursue graduate studies in cancer treatment or a related area. In the post-site survey, participants had the opportunity to comment on their experience and whether they would recommend the program. Free text responses were received from 5 respondents. All of the comments were positive.

Comments	Sentiment
Experience is valuable and a glimpse into graduate research, it's also very enjoyable and you are with friendly students with great academic energy	Positive
I enjoyed my time here and I would do this program again if given the opportunity. They provided me with a great space where I can hone my research skills as well asmy literature skills.	Positive
It not only allowed me to explore current research regarding cancer treatment through my project but also through the other people in the program. I learned so much and made many connections.	Positive
The internship application was very easy and coordination with the program director before coming out here was also very smooth. The traveling and living conditions were excellent. In regard to my project, my professor as well as the graduate students were very helpful. The seminars, talks, and luncheons were also very informative. Overall, a great learning experience I would recommend	Positive
I would recommend this program because it is a good, hands-on-experience, especially for those with no prior experience. It also allows you to meet students and mentors in the field and learn new valuable information	Positive

Table 6: Summary of Site objectives, activities, and data collection for Cancer Innovation REU

V. Program Impact and Conclusion

The Undergraduate Research and Innovation Experience in Cancer Diagnosis and Therapeutic Intervention program at NJIT has been able to foster a community and atmosphere that integrates research, education, and training activities for students from underrepresented minority groups. Such groups include African Americans, LatinX, women, students with disabilities and first-generation college students. By targeting specific universities with limited research facilities, we are able to recruit strong groups of talented individuals, eager and passionate to learn about cancer-related research. Our mentor pool of renowned researchers is able to engage undergraduate students to conduct innovative on research cancer diagnostics to therapeutic intervention. The work students accomplish during the REU has real world impact, as seen through multiple conference abstracts and presentations, as well as high-impact publications. The REU has been able to cultivate and communicate multidisciplinary research. These communications are not only soundly science-based, but come from the voices and perspective of members of our community that are often underrepresented. Participants in the REU are allowed to grow professionally through a number of seminars. Assessment of the program revealed students’ appreciation

to connect with a variety of STEM graduate students and professionals during our innovation luncheons series. The series helped the students to figure out where their interest lie, and in many instances, motivated them toward pursuing graduate studies. Lastly, we see the impact of the REU, as students become strong candidates for high-level internships, post-undergraduate programs and industrial positions. From the proven successes of this National Science Foundation funded research experience for undergraduates, the PI and coPI of this grant will seek a renewal of funds to support an additional three years. We will implement changes based on the program assessment. We will also include activities for students to tell more of their unique stories through a series of filmed interviews that will also be used as content for communication to a wider audience of underrepresented student. Lastly, we will expand the program assessment to evaluate self-efficacy of students before and after the 10-week program. This REU will continue to strive to: 1) increase the number of undergraduates participating in research projects focused on cancer related research; 2) increase communication of bio-inspired science and engineering to undergraduate peers, faculty and general audience; and 3) diversify the supply of scientists and engineers contributing to American industries and economics as a whole.

[1] American Cancer Society. Cancer Facts & Figures 2023 (2023) Available at: https://www.cancer.org/research/cancer-facts-statistics/all-cancer-facts-figures/cancer-facts-figures-2023.html [accessed 5 February 2024].
[2] S. McGuire. McGuire S. World Cancer Report 2014. Geneva, Switzerland: World Health Organization, International Agency for Research on Cancer, WHO Press, 2015. Adv Nutr. 7(2):418-419, 2016.
[3] D. Spano, C. Heck, P.D. Antonellis, G. Christofori, M. Zollo. Molecular networks that regulate cancer metastasis. Semin. Cane. Biol. 22(3): 234-249, 2012.
[4] M.K. Fiegener, S.L. Proudfoot. (2013) Baccalaureate origins of U.S.-trained S&E doctorate recipients. Available at: www.nsf.gov/statistics/infbrief/nsf13323 [Online: accessed 23 August 2021].
[5] S. Aud, M. Fox, A. KewalRamani. (2010). Status and trends in the education of racial and ethnic groups. National Center for Education Statistics. Available at: https://nces.ed.gov/pubs2010/2010015.pdf [Online: accessed 23 August 2021]
[6] W. Erickson, C. Lee, S. von Schrader. (2016). 2015 Disability status report: United States. Yang-Tan Institute on Employment and Disability, Cornell University. Available at: http://www.disabilitystatistics.org/StatusReports/2015-PDF/2015-StatusReport_US.pdf [Online: accessed 23 August 2021]
[7] Women, minorities, and persons with disabilities in science and engineering: 2017. Special Report. (2017) National Science Foundation, National Center for Science and Engineering Statistics. NSF 17-310.
[8] Y. Pearson Weatherton, R.D. Mayes, C. Villanueva-Perez. "Barriers to persistence for engineering students with disabilities," in Proceedings of the American Society for Engineering Education Annual Conference and Exposition, Columbus, OH, 2017.
[9] H. Gao, Q. He. The interaction of nanoparticles with plasma proteins and the consequent influence on nanoparticles behavior. Expert Opin Drug Deliv.11(3):409-20, 2014.
[10] T.M. Göppert, R.H. Müller. Adsorption kinetics of plasma proteins on solid lipid nanoparticles for drug targeting. Int J Pharm.302(1-2):172-86, 2005.
[11] J.L. Perry, K.G. Reuter, M.P. Kai, K.P. Herlihy, S.W. Jones, J.C. Luft, M. Napier, J.E. Bear, J.M. DeSimone. PEGylated PRINT nanoparticles: the impact of PEG density on protein binding, macrophage association, biodistribution, and pharmacokinetics. Nano Lett. 12(10), 5304-10, 2012.
[12] H. Zou, Z. Wang, M. Feng. Nanocarriers with tunable surface properties to unblock bottlenecks in systemic drug and gene delivery. J Control Release. 214:121-33, 2015.
[13] M.S. Bannon, A. López, K. Corrotea, M. Marquez, Z. Wallizadeh, M. Savarmand, C.A. LaPres, J. Lahann, K. McEnnis, Nanoparticle Tracking Analysis of Polymer Nanoparticles in Blood Plasma. Part. Part. Syst. Charact. 38, 2100016, 2021.
[14] P.K. Sorger. Microfluidics closes in on point-of-care assays. Nat Biotechnol, 26(12):1345–1346, 2008.
[15] Crosby, F. J. (1991). Juggling: the unexpected advantages of balancing career and home for women and their families. New York: Free Press.
[16] Sirgy, M., Lee, DJ. Work-Life Balance: an Integrative Review. Applied Research Quality Life 13, 229–254 (2018). https://doi.org/10.1007/s11482-017-9509-8
[17] R. Lorenzo, N. Voigt, M. Tsusaka, M. Krentz, K. Abouzahr (2018). How Diverse Leadership Teams Boost Innovation. Available at: https://www.bcg.com/publications/2018/how-diverse-leadership-teams-boost-innovation [Online: accessed 6 February 2024]
[18] National Science Board, National Science Foundation. 2020. Science and Engineering Indicators 2020: The State of U.S. Science and Engineering. NSB-2020-1. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20201/; US Census, 2021 [Online: accessed 6 February 2024]
[19] National Science Board, National Science Foundation. 2019. Science and Engineering Indicators 2020: Science and Engineering Labor Force. Science and Engineering Indicators 2020. NSB-2019-8. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20198/. [Online: accessed 6 February 2024]
[20] López Ruiz, A., Xiao, M., Sathya, A., Piccininni, N., Liu, G., Siddiq, N., Chen, H., & McEnnis, K. (2023). Influence of particle z-potential and experimental procedure on protein corona formation and multicomponent aggregation. AIChE Journal, 69(12). https://doi.org/10.1002/aic.18237