

# EFRI-REM at CCNY: Research Experience and Mentoring for Underrepresented Groups in Cross-disciplinary Research on Assistive Technology

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***Abstract* - We have successfully run the NSF EFRI-REM program at The City College of The City University of New York (CUNY) for four years (2012 to 2015) with over 50 research participants (RPs), most of whom are from underrepresented groups, particularly individuals who are disabled, women, veterans and minorities. Each year we started with an 8 to 10-week summer research program and then mentored the participants' education and career paths in the following academic year. We have not only provided exciting cross-disciplinary, student initiated research opportunities in human and machine vision research and applications in assisting visually impaired people, but also shaped an innovative model to support career development of high school students, community and senior college students, graduate students (mentors), high school teachers, as well as community college professors. The EFRI-REM program provides a novel and effective platform to allow more underrepresented students in the greater NYC area to participate in our multidisciplinary research.**

*Index Terms* – career development, diversity and inclusion, human and machine vision, pipeline mentoring structure.

## INTRODUCTION

Emerging Frontiers in Research and Innovation (EFRI, <http://www.nsf.gov/eng/efma/efri.jsp>) is the signature program for the Office of Emerging Frontiers and Multidisciplinary Activities (EFMA) at the National Science Foundation (NSF). Since 2012, NSF encourages EFRI-supported researchers to create carefully mentored research opportunities for people who may not otherwise become engaged in a research project and to utilize contributions and talents of these participants to make further progress towards research goals. All eligible undergraduate STEM students, high school students and STEM teachers (US citizens, nationals and permanent residents) are encouraged to apply for a six to ten-week intensive research program as Research Participants (RPs). Priority is given to *underrepresented groups*, including persons with

disabilities, females, veterans and underrepresented minorities, as well as faculty and students from community colleges who usually do not have such research opportunities in their institutions. The RPs have opportunities to work in research labs, with mentoring from both faculty and PhD students, on cutting edge research projects sponsored by the NSF EFRI program.

The EFRI-REM at the City College of New York (CCNY) focused on Mentored Research Experience in Multimodal and Alternative Perception for Visually Impaired People (MAP-VIP). We ran the EFRI-REM program at CCNY for the last four years, gradually developing it into a rigorous mentoring program to bring in research participants (RPs) who have unique challenges to benefit both the RPs and the project. In addition to the strong diversity of the team, the cross-disciplinary research, student initiation of projects, and the involvement of the visually impaired, the program in 2015 has the following three unique components: (1) *A Career-Oriented Mentoring Plan* - With a pipeline mentoring structure that started in 2012, we added a career training workshop session each week, together with a “career chat” featured during each week’s lab meeting; details on the career chat will be provided later in the paper. (2) *A Rigorous Recruiting Plan* - We improved upon a formal recruiting plan that we started in 2014 with institutional support to attract a broader pool of students that allowed for better RP-mentor matches. (3) *A Concrete Outreach/Partnership Building Plan* – we have developed long-term partnerships with Borough of Manhattan Community College (BMCC) and a number of high schools in NYC, including Eleanor Roosevelt High School (ERHS) and Brooklyn Technical High School.

The MAP-VIP REM program experience will be detailed in the following sections. Our multidisciplinary research project under the topic of Man, Machine and Motor Control (M3C) will be described first to set up the context of our EFRI-REM program. Then, we will provide a brief history of the development of the CCNY REM Program during the first three years (2012 to 2014), which gradually shaped into the form of the REM 2015 Program. The overview of the REM 2015 will be followed by the

description of three main parts of our REM program: mentoring and career development activities, samples of research projects, and outcomes and surveys. The paper concludes with a summary and further discussion of our REM program.

### **EFRI-M3C: OUR MULTIDISCIPLINARY RESEARCH**

Over the past four years, the three principal investigators (PIs) (Z. Zhu, T. Ro and Y. Tian) of CCNY and two collaborators at Georgia Tech (K-M Lee and B. Prilutsky) have been working on assistive technologies for helping the blind and visually impaired for the EFRI-M3C project (#1137172): EFRI-M3C: Mobility Skill Acquisition and Learning through Alternative and Multimodal Perception for Visually Impaired People. At CCNY, the faculty members were from three different departments (computer science, psychology, and electrical engineering) with diverse expertise in multimodal sensing, computer vision, and human perception and action. The EFRI-M3C project pushes the research of assistive technologies to a new level, with its goal to develop models for characterizing sensorimotor control through man-machine learning as the basis to establish a set of design criteria for developing improved assistive technologies for visually impaired and blind people. Studies in this project promise to lead to new design concepts of “alternative perception” and methods to formulate “required information”, capitalizing on multimodal (visual, audio, tactile, thermal, etc.) information for developing cost-effective mechatronic devices to assist visually impaired people in achieving mobility functions comparable to people with normal vision.

Ever since this project began in 2011, we have attracted a great deal of attention from both the blind community and underrepresented students at CCNY. Through our advisory board members, we are in close contact with the New York State Commission for the Blind and Visually Handicapped (CBVH), which helps visually impaired individuals in career development, Lighthouse Guild, which provides comprehensive vision rehabilitation services, and the New York Institute for Special Education (NYISE), which serves hundreds of blind students ranging from 5 to 21 years of age. CCNY is one of the most diverse campuses in the U.S., with a student body of about 35% Hispanics and 25% African Americans. As a major urban university in the heart of New York City, we also host many students who have various disabilities, as well as students who are veterans. The multidisciplinary nature of the EFRI-M3C project provides an excellent platform to bring together young talents under one unified and exciting research program, recruited from three traditionally separate disciplines (computer science, engineering, and psychology).

However, our EFRI-M3C research grant mainly supports PhD students as research assistants. The establishment of the EFRI-REM pilot program as a novel and effective platform has enabled us to fully implement our ideas and plans for outreaching to the major underrepresented groups at our university and in the New

York City area: minority/female students, veterans, and disabled individuals (particularly those who are blind).

### **THE CCNY REM PROGRAM: 2012-2014**

Before 2015, we successfully ran the EFRI-REM program for three years (from 2012 to 2014). The REM program at CCNY brought in underrepresented students (i.e. disabled, women, veterans and minority) to our 10-week research program each summer, with continued involvement in the following school year. REM Research Participants (RPs) have been involved in exciting projects such as assistive navigation, people tracking, accessible games for the blind using RGB-D sensors, wearable sensors for travel assistance, speech recognition using lip and electromyography (EMG) readings, 3D game engine for multimodal sensing evaluation, tongue stimulation for the blind, and vision for the blind with smartphones.

#### *I. REM 2012*

With EFRI-REM supplement grant support for the summer of 2012, we recruited from our pool of underrepresented students, 7 undergraduates and 1 master’s level graduate student who were motivated and talented but were not able to easily participate in regular research programs, either because of their personal/financial disadvantages or because of the stage of their studies. A high school student at Bronx Science also participated in the research. We also invited one teacher and two blind high school students from NYISE as “observers” who came to our lab meetings once a week, experienced the research we were doing, and offered feedback on the usefulness of our studies. We started to use a pipeline mentoring mechanism, designed project-oriented summer research and teamwork, and performed a project evaluation. From the 2012 cohort, the master’s student (low vision/legally blind) was admitted to our Computer Science PhD program at CUNY and two other students (one female and one veteran) received offers for PhD programs in Psychology. The veteran postponed his PhD study and decided to work as a high school science teacher, partially inspired by the need of our high school participants. The female student is now in her third year of a doctoral program. Two journal publications [1, 2] and a number of conference papers [3, 4] have been co-authored by RPs, their PhD student mentors and PIs. The REM RPs brought in a fresh perspective to our research, leading to innovations in wearable sensing devices and sensor evaluation methodology. The use of the game engine, Unity3D, initialized by our undergraduate students, has not only attracted great interest from students at all levels, but also provided a new approach in evaluating an array of multimodal sensors, including cameras, RGB-D sensors, and IR/sonar rangefinders in realistic environments.

#### *II. REM 2013*

In 2013, not only did we recruit a majority of research participants from underrepresented groups (2 females, 4 minority, 2 disabled, and 2 community college students),

but we also incorporated three important extensions to the program: (1) Participation of faculty and students from the Borough of Manhattan Community College (BMCC); (2) Collaboration with Carnegie Mellon University's Quality of Life Technology (QoLT) Center, with one undergraduate RP (African-American), one PhD student mentor (Hispanic) and one community college junior faculty conducting their summer research at CMU; (3) Attendance by 10 people of the REM 2013 team at ICME 2013 in San Jose, CA, *IEEE/NSF Workshop on Multimodal and Alternative Perception for Visually Impaired People*, organized by the PIs in conjunction with ICME 2013 and sponsored by NSF, and the *Third Greater NY Area Multimedia and Vision Meeting*. More than six papers including [5-10] have been presented in conferences/workshops by the team in addition to three presentations at 2014 Emerging Researchers National Conference in STEM (ERN 2014), where REM began to have a special session (all three received ERN travel awards). The CS undergrad student (African-American) who went to CMU for the summer accepted a software engineering job at Thomson Reuters with a high starting annual salary. The two community college students transferred to CS at Columbia University in 2014. The high school student, at Bronx Science was admitted to NYU Polytechnic School of Engineering in 2014. Finally, as outcomes of this project and NSF-I-Corps, an undergrad RP (Computer Engineering) and two PhD student mentors (CS and Psychology) started a small business, Vista Wearable, Inc. A regular patent was filed by CUNY on behalf of the team on our wearable navigation assistance devices [11].

### III. REM 2014

In 2014, Dr. Yuying Gosser, Director of Student Research and Scholarship in the Grove School of Engineering at CCNY, joined the team for student recruitment with an open call for applications, which attracted a large number of applications. REM 2014 accepted a total of 17 RPs, including 10 undergraduate students from CCNY, Cornell, BMCC, 5 high school students from Brooklyn Technical (BTHS) and Eleanor Roosevelt High School (ERHS), 1 ERHS teacher, and 1 junior community college faculty member, Dr. Hao Tang. Among the 17 RPs (some part-time), 4 were female, 3 Hispanic, 2 African American, and 1 with disability (Autism). In addition to the three PIs, the team had 5 Ph. D. student mentors, one of whom was also a program coordinator (Mr. Wai L. Khoo). Based on each RP's interest, he/she was assigned to a primary mentor from one discipline and a secondary mentor from another discipline, creating a multidisciplinary team. Each RP had a project that was relevant to his/her primary mentor's thesis project; this allowed the RPs to understand the relevance of their projects in the overarching NSF project. The project was usually one or two subtasks from the mentor's project; therefore, it was achievable in a few months. This 2014 REM program had many exciting projects, for example, game design for evaluating multimodal sensors, smartphone app development for blind navigation, vibrotactile

sensor/feedback design and human subject testing, a Kinect audio game for the blind, and transcoding 3D content (i.e. geometry) to the blind using audio and tactile feedback via smartphones. The projects were designed in such a way that there was no direct competition among RPs, but rather with some overlap such that they could collaborate or learn from each other. This research experience was enhanced with several social events. For example, the students visited the Intrepid Museum with a question in mind: "how can we help the blind visit this museum?"; they visited The New York Institute for Special Education (NYISE) to learn how visually impaired children acquire skills needed to survive in New York City and brainstormed on how our projects can augment their skills set. They also attended talks and entrepreneurship seminars as educational experiences and for networking. This year, 7 project teams (each with an undergrad RP as the leading author) and 4 high school RPs presented their work at ERN 2015 (3 received ERN travel awards). The high school science teacher at ERHS developed a new science curriculum based on his students' research experiences in this program. One of the high school students won the best poster award in the category of REM high school students/teachers, and an undergraduate student co-authored a conference paper [12].

### CCNY REM 2015: OVERVIEW OF THREE FOCUSES

After running the REM program for three years, for REM 2015 we created a formal model to more directly support the career development of the RPs at various stages of their studies: from high school students, community and senior college students, graduate students (mentors), high school teachers, to community college professors. In order to achieve this goal, we have had three major focuses in 2015.

#### I. A Career-Oriented Mentoring Plan

We have continued the pipeline mentoring structure that we had in the past. However, a lesson we learned from prior years is the importance of setting clear and consistent goals at the beginning of the program that align with the RP's short, medium and long-term career plans. As such, Camille Santistevan, Education & Outreach Manager at the CUNY Advanced Science Research Center (ASRC), coordinated weekly career development workshops that ran simultaneously with their summer research activities. In addition to developing a curriculum for the career development workshop, she also created evaluation tools to assess the program as a whole. Because the REM program targets students at all levels, the curriculum and evaluation sought to address the diverse needs of each group: (1) preparing undergraduate students for graduate studies or STEM careers; (2) attracting high school juniors to STEM majors in college; (3) facilitating student transfer and career training for the community college students and junior faculty.

#### II. A Rigorous Recruiting Plan

We continued to use the formal recruiting plan with an open call for applications that we started in 2014 with institutional support to attract a broader pool of students from the communities. After reviewing resumes, research/career plan statements and reference letters and an initial selection by PhD student mentors and PIs from the application pool, we held face-to-face interviews with the selected candidates. The mentors then picked their potential mentees, and a refined candidate list was generated. After this we contacted the candidates on the list with the RP-mentor match and possible project information for further adjustments. A final decision was made based on mutual agreements between mentors and RPs.

### III. A Concrete Outreach/Partnership Building Plan

In the summer and during the subsequent academic year of REM 2015, we developed longer-term partnerships with BMCC through Prof. Hao Tang, ERHS through the high school science teacher, Mr. Chin-Sung Lin, and NYS companies through Ms. Camille Santistevan at CUNY ASRC and Dr. Edgardo Molina at Vista Wearable, Inc., a research spinoff company incubated at the CCNY Zahn Entrepreneurship Center. The plan is to develop joint proposals in the future for bridging university research and curriculum development in STEM education at CCNY with both community colleges and high schools.

#### MENTORING AND CAREER DEVELOPMENT ACTIVITIES

While many aspects of our mentoring plan were similar to previous years, the addition of the weekly career development workshop in 2015 emphasized the mentoring relationship and strengthened the RPs perceptions of how their research activities were tied to their larger career goals. The summer commenced with a new mentor training for the PhD student mentors and PIs. While most of the 2015 mentors already had extensive mentoring experience, the training provided them an opportunity to review mentoring and coaching best practices and the literature on positive youth development.

The rationale behind the addition of the workshop comes from social scientific research on career development among youth ages 16-24. Evidence shows that career development programming is most successful when career development services are individualized, coupled with real-world work experiences, and provide opportunities for peer support [13-16]. The career development workshop sought to unify the REM model's existing evidence-based characteristics by providing an opportunity for students to meet in an informal capacity for peer support and receive individualized feedback on their career plans.

#### I. General Mentoring Mechanisms

Pipeline structure of the mentoring. We have followed our pipeline structure for mentoring, which was successfully used in the summers of 2012 to 2014. The REM 2015 mentoring structure and demographics of RPs are listed in

Table 1 and part of them are shown in Figure I. Note that in order to implement the three new focuses described in the previous section, we enhanced the program coordination layer by adding two coordinators (Santistevan and Molina) in career development and entrepreneurship training, in addition to coordinators in recruitment/dissemination and research/development we have had since 2014.

TABLE I

CCNY EFRI-REM 2015 TEAM. DEMOGRAPHICS: (F) - FEMALE, (U) - UNDERREPRESENTED MINORITY, (D); PERSON WITH DISABILITIES. LEVELS/DISCIPLINES: CC- COMMUNITY COLLEGE; UG- UNDERGRADUATE COLLEGE; HS- HIGH SCHOOL; CS – COMPUTER SCIENCE; NS- NEUROSCIENCE; EE-ELECTRICAL ENGINEERING)

PI and Co-PIs	Zhigang Zhu /CS, Tony Ro /NS, Yingli Tian (F) /EE
Program Coordinators	Career Development & Evaluation: Camille Santistevan (F); Recruitment & Publicity: Yuying Gosser (F); Research & Development: Wai L. Khoo; Entrepreneurship: Edgardo Molina (U)
Project Mentors	Hao Tang /CC faculty, Chin-Sung Lin /HS teacher, Greg Olmschenk /CS, Feng Hu /CS, Farnaz Abtahi (F)/CS, Wei Li /EE, Lei Ai /NS
RPs (continuing and new RPs)	5 UG students, 3 CC students and 1 CC faculty, 3 HS student and 1 HS teacher: total 13 RPs from underrepresented groups: 8 (including 4 females, 3 minorities, 1 with disabilities)



FIGURE I

REM 2015 COHORT (PART): PIs, MENTORS AND RPs

Guidance and role models of PIs and faculty/student mentors. In addition to the weekly meetings in which PIs provided technical and educational guidance to mentors and RPs for research planning, technical writing/reporting, collaboration skills, and presentation training, several of our PIs and mentors also served as role models for our RPs. For example, Prof. Tian, a female professor, is a role model for our female students. Prof. Tang, a recent CUNY PhD graduate and a community college professor is a role model for our PhD student mentors. Dr. Gosser and Ms. Santistevan (both female) provided alternative career paths through their work in the Office of Student Research and Scholarship and the CUNY ASRC, respectively.

Student involvement and networking. Based on our prior the experiences, we also emphasized student initiated and student-led projects and meetings in 2015. In 2012, we specified unique topics to RP candidates. In 2013, we only provided guidelines to propose projects. In 2014, we trained RPs to develop their own ideas with their mentors, based on

the information we had provided for them. In REM 2015, we have continued to encourage RPs to develop their own ideas with guidance, as needed, supported by our career development activities, as well as creating other opportunities for RPs to go to other institutions; for example, three members of the REM team (a faculty, a PhD student and an undergraduate student – not shown in Fig. 1) were selected and paid by the US Department of Homeland Security (DHS) summer research program in the Command, Control and Interoperability Center for Advanced Data Analysis (CCICADA) - a DHS University Center of Excellence at Rutgers. We have also encouraged mentors and RPs to organize meetings and events, such as science fairs, professional networking and outings. Six of us attended the 2015 STEMfest at a high school - Highland View Academy, showing our demos and organizing a breakout session.

Cross-boundary research. We treasure our multidisciplinary team, which includes researchers from fields including computer science, neuroscience and electrical engineering. PIs and students in these three fields have seamlessly worked with together in experimental design, algorithm development, hardware design, and joint publications.

## II. Specific Mentoring Objectives

Research on out-of-school time career development programs has found that “programs with high recruitment and retention often provide youth with opportunities to experience the real world, learn new skills, make a difference in the community, and practice autonomy and decision making” [15]. In this spirit, our program has defined the following three mentoring objectives:

(1) Experience in undergraduate research. During daily mentoring/training, the mentors taught RPs about the general research process and how to convert a good idea into a viable research project (i.e., literature review, topic selection, programming/implementation, data collection, experiment, data analysis and writing report). Usually, a number of barriers prevent undergraduates from performing good research including research inexperience, social and mental immaturity, and time management. The mentors were well aware of the above problems and helped RPs to break down these barriers. For example, the mentors did not assume anything about the RPs' previous knowledge, experience, or work ethic in the research environment. One-to-one mentoring increased peer-to-peer communication and helped mentors to identify when the RPs needed assistance.

In addition to the regular mentoring plan, we offered two specific activities for the REM RPs: (1) A half-day end of the summer workshop at CCNY [17] was organized for RPs and mentors to present their projects to individuals from governments, industry, academia, communities and families. We also invited professionals, researchers and former REMers as panelists during the workshop. (2) All RPs are encouraged to submit their work to ERN 2016. Among the seven undergraduate RPs who submitted their work to ERN 2016, five have received travel awards. These two activities

are anchors for our summer program and beyond by providing RPs realistic deadlines to train them in technical presentation and writing.

(2) Experience in small business. We referenced the startup Vista Wearable, Inc. - a company created by REM RPs - as an example for students to learn how STEM related activities can become involved with industry. The company is a strong case study as it has taken advantage of several entrepreneurship programs including SBIR and VentureWell (formerly NCIIA) E-TEAM proposal writing, and CCNY Zahn Center Entrepreneurship Competitions. This was coupled with our joint senior design program between the CS and EE departments. Research participants experienced first-hand exposure to the commercialization process from our student entrepreneurs. Vista Wearable is commercializing an assistive device for the blind, a technology partially developed as part of NSF EFRI and a REM supported research project. As members of the PI's labs, the team shared with RPs their experiences in forming a company, rapid prototyping of technologies, and writing funded grant proposals. Prof. Zhu's Visual Computing Lab has also produced senior capstone teams that have entered entrepreneurial competitions and two teams have previously won, one of whom won the first prize of the 2011 Kaylie Competition. Those students that continue through the year with their REM projects are encouraged to consider developing prototypes and to research the markets that their innovations can impact. Based on our previous students' experiences, even teams that didn't win the competition gained invaluable experience.

(3) Experience in graduate research. Pairing RPs to appropriate mentors allows RPs to see the relevance of their project to graduate research. Furthermore, RPs actively participate in the research process guided by the mentors (through daily mentoring). A newcomer coming into STEM or research might see a project as a daunting task, mostly because they're not familiar with the research process or applying their theoretical foundation into practice; breaking this barrier is a crucial step in retaining the RPs in research and STEM related fields. With daily mentoring, the mentors can guide the RPs with a hands-off approach. Guiding can consist of suggesting the next steps, working alongside the RPs to work through a challenge, providing insights or experiences to a problem they had encountered, providing presentation guidelines, teaching them scientific writing, etc. Thus, the RPs experience first-hand participation in the research with their mentors. Lastly, the RPs' projects came to a visible fruition via technical presentations and papers at the end of summer workshop, a national conference (ERN 2015), and even to international conferences such as the International Technology and Persons with Disabilities Conference [18, 19].

## III. Networking and Career Development Activities

Traditional graduate programs prepare students to excel in an academic environment, however, to retain or recruit students into STEM careers, we need to do a better job

showing them the various career opportunities within STEM fields and how to develop the soft skills necessary to succeed in the professional world. REM 2015 includes three career development components: career workshops, peer support and “career chat.”

*Career Workshops.* Ms. Santistevan’s weekly workshop covered topics ranging from how to set SMART goals (specific, measurable, attainable, relevant, and time-bound) to how to present professionally during an interview. Table II shows the complete list of topics covered. The workshop also provided RPs a space to troubleshoot immediate research challenges and to connect these challenges to their career goals.

TABLE II  
REM 2015 CAREER WORKSHOP

Week	Content
Week 1	Career Exploration & Setting SMART Goals
Week 2	Building Professional Relationships
Week 3	Conducting “Opportunity” Searches
Week 4	Resumes, Cover Letters, & Applications
Week 5	Interviewing
Week 6	You got the job/internship/admission letter! Now what?
Week 7	Entrepreneurship & Intrapreneurship
Week 8	Wrap-up & Next steps

*Peer Support.* The career workshops also provided space for the RPs to meet in groups to explore their mutual interests and share their own knowledge of career-related information. Ms. Santistevan facilitated interactive assignments such as career mapping, resume writing, and portfolio development. And whenever possible, the RPs would swap drafts and provide each other feedback on these assignments. In these sessions, RPs often shared what they knew about upcoming conference opportunities, entrepreneurship competitions and other professional networking events that they could attend.

*Career Chat.* In addition to faculty members on our team and our graduate students giving career advice and answering RPs’ questions about choosing the right career or graduate school/major, we invited dynamic professionals from academia, government, and industry to share their career experience, including former EFRI-REM RPs. For example, Dr. Quynh Dinh, a woman engineer from MakerBot working on 3D printing, encouraged our female RPs to continue their STEM study and be proud women scholars. Dr. Nicholas Giudice, a blind user and professor at UMaine, gave us insights in how blind need/use assistive technologies, especially visually impaired students trying to get into STEM fields. In addition, the panelists in the Career Chat Panel at the 2015 REM Final Meeting also shared their life stories, decision-making moments, and career paths [17]. The panelists themselves are also from underrepresented groups, including: Mr. Garie Fordyce (NSF EFMA Program Manager); Dr. Ashiwel Undieh (Associate Provost for Research, CCNY), Dr. Rosemarie Wesson (Associate Dean for Research, GSOE, CCNY), Ms. Barbara Campbell (Sr. Vocational Rehabilitation Counselor, NYSCB), Dr. Shirshendu Chatterjee (Professor of Mathematics, CCNY), Dr. Edgardo Molina (Co-Founder

and CEO, Vista Wearable Inc.). Students and families’ feedback: Very touching and inspiring!

## REM 2015 PROJECT TOPICS

Based on our past experience, we broadly have following topic areas, all related to our current EFRI-M3C project.

### I. Virtual Environment Designs and Navigation

This project focuses on the development of games and interfaces with Unity3D, a 3D game engine in order to: (1) test multimodal sensors that could be simulated in Unity3D (including color, depth, visual signs, acoustic, etc.) and transduced to real actuators (such as audio and haptic feedback) that are worn by users; (2) train users with certain devices (such as our range-vibrator devices) in a virtual environment; and (3) provide blind-friendly games through active exploration of the virtual environment by alternative perception. The development includes 3D scene modeling, real-time 3D rendering, multimodal sensor simulation, and interfaces to other devices via USB, Arduino, Bluetooth, etc. The projects in this topic involve both engineering (CS, EE) and human factors (psychology, arts and designs).

### II. Wearable Designs w/ Arduino and Bluetooth Technology

This project is in collaboration with Vista Wearable, Inc., a startup company run by our former students, aiming to develop assistive navigation devices for the blind. The tasks in this topic include (1) integrating smart sensors and actuators, including IR rangefinders, vibrators etc. (2) designing hardware interfaces for the sensors using microcontrollers and smartphones; (3) programming microcontrollers and smartphones for control and communication; and (4) designing wearable devices that satisfy requirements of both functionality and aesthetics. Each RP focuses on one task, but all tasks require the RP to engage with the blind and visually impaired community to understand the challenges and needs of the users. While collaborating with Vista Wearable, RPs also experience the business side of the projects. The projects in this topic involve both engineering (CS, EE) and human factors (psychology, arts and designs).

### III. Mobile Computing for Detection and Recognition

RPs learn programming skills to develop algorithms of text/object detection and recognition on smartphones, other wearable, or mobile devices (such as Google Glass and RGB-D sensors), for assisting visually impaired people. The projects under this topic include (1) corridor detection using a smartphone; (2) sign detection with a wearable camera such as Google Glass or a smartphone; (3) text reading and text enhancement for the visually impaired; (4) daily objects detection with a smartphone, a RGB-D sensor, or a regular camera; and (5) pedestrian and face detection/recognition using Kinect or other RGB-D sensors.

### IV. Multimodal Sensor-Assisted Navigation

RPs are involved in human subject experiments for evaluating the technologies in assisting visually impaired

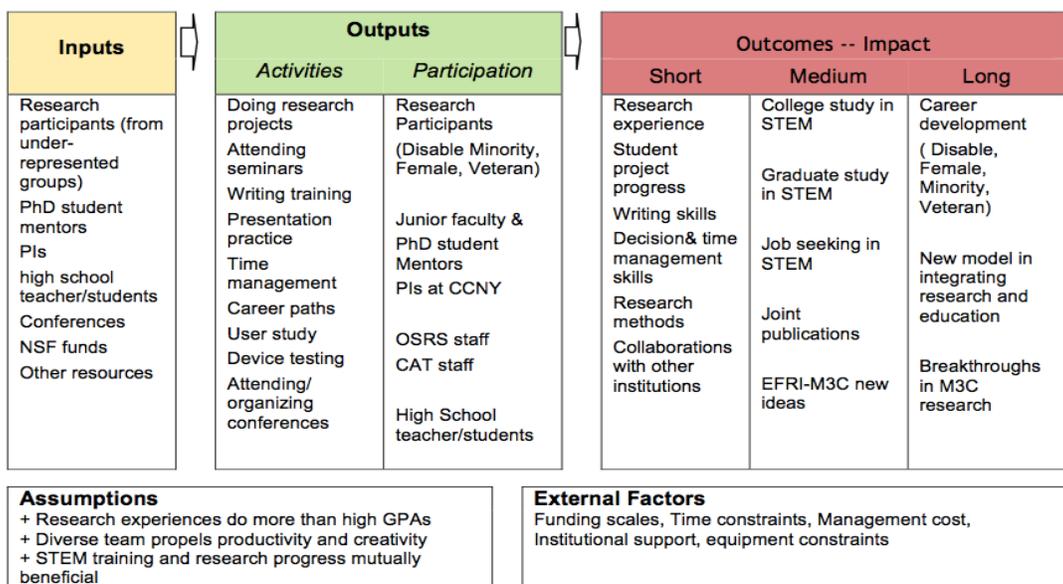


FIGURE II  
LOGIC MODEL FOR PROGRAM EVALUATION: GENERAL OUTCOMES

people in recognition and navigation. The RPs are given basic training in conducting experiments with human subjects and observing confidentiality protocols. This topic focuses more on human vision and neuroscience and requires students with multidisciplinary backgrounds (CS, EE, or Neuroscience). The projects include (1) evaluating range-vibrotactile devices for indoor navigation of visually impaired people in real and virtual environments; (2) finding the optimal amount and placement of both sensors and stimulators on the body; and (3) evaluating indoor navigation with multimodal sensors (such as cameras and RGB-D sensors) in real and virtual environments. Human subjects (both sighted and visually impaired) were recruited with our existing IRB approval.

### OUTCOME AND SURVEYS

Table III summarizes the demographic numbers of our participants between years 2012 and 2015. We have trained a total of 52 RPs over the period the four years, including high school students, senior and community college students, community college faculty and high school teachers, with an age range from 16 to over 60. Over 70% of them are from underrepresented groups, where Under-represented Individuals (URI) are defined by NSF REM as those include: Females (F), URM (U), CC Students (C), Persons with Disabilities (D), and Veterans (V): the numbers in the URI column have overlaps, for example, some RPs are both URM and Females. At the writing of the paper, we are still in the middle of REM 2015, but results from the previous three years (2012-2014) and REM 2015 so far include: a best REM poster award to a high school student in ERN 2014; 3 community college students transferred to Columbia University (2) and SUNY Stony Brook (1); 3 accepted into CS or psychology PhD programs; 4 high school seniors admitted to top universities (MIT,

RPI, Harvard, NYU Poly); 6 found their dream jobs; two journal papers [1,2] and more than ten conference papers [3-10, 12, 18-19] have been published (or accepted); and almost all the RPs stay in STEM fields. After participating in our REM program for two years, ERHS teacher Mr. Lin and his students brought back the research experience to his small humanities high school and enriched his dynamic project-based STEM curriculum model [22]. We are now looking into a new STEM research paradigm for college-high school collaboration.

TABLE III

REM 2012-2015 RESEARCH PARTICIPANT STATISTICS (CoS: COLLEGE STUDENTS; CCF: COMMUNITY COLLEGE FACULTY; HSS: HIGH SCHOOL STUDENTS; HST: HIGH SCHOOL TEACHER, UNDER-REPRESENTED INDIVIDUALS (URI) AS DEFINED BY NSF REM INCLUDE FEMALES (F), URM (U), COMMUNITY COLLEGE STUDENTS (C), PERSONS WITH DISABILITIES (D), AND VETERANS (V).

YEAR	SUM	URI(F/U/C/D/V)	CoS	HSS	HST	CCF
2012	12	10(5/3/0/5/1)	8	3	1	0
2013	11	8(2/3/2/2/0)	8	1	1	1
2014	17	10(4/5/3/1/0)	10	5	1	1
2015	13	8(4/3/3/1/0)	7	3	1	1
TOTAL	52	36(15/14/8/9/1)	32	12	4	3

To evaluate our program this year, we designed a logic model for our program evaluation (Figure II), and carried out voluntary pre- and post-surveys of participants (research participants, faculty and PhD student research mentors) at the beginning and the end of the summer. The survey questions were adapted from existing instruments [20-21].

The program evaluation assessed the impact of the REM 2015 project thus far on RPs research, communication, and general “soft” skills and their desire to pursue a degree and/or career in STEM. RPs were asked to assess themselves in these areas. PhD mentors assessed their own mentoring skills as well as the skill levels of the RPs they were working with. The levels were measured from 1

(lowest) to 6 (the highest). We had an 81% response rate for both the pre- and post-surveys and a 100% response rate for mentor surveys. The survey results show that RPs' skill levels improved in nearly all areas, thus showing that the short-term outcomes listed in Figure II were achieved. Table IV shows the skills that RPs and their mentors reported improving upon the most during the course of the summer, which include critical skills needed to be both a professional and a researcher, such as analyzing data, time management, and dealing with set-backs.

TABLE IV  
REM 2012-2015 SURVEY RESULTS

Question	RP Pre	RP Post	Mentor Pre	Mentor Post
Analyzing data	3.56	4.79	3.89	5.20
Figuring out next steps in research	3.56	5.00	4.00	5.10
Keeping a detailed lab notebook	2.89	4.67	4.13	5.20
Writing a scientific report of paper	3.00	4.22	3.88	4.90
Time management	2.89	4.56	4.67	5.10
Dealing with set-backs	3.33	5.00	4.88	5.20

In the post-survey, RPs also assessed the usefulness of the career development workshop, the mentoring skills of their assigned mentor, and the overall impact of the program on their career goals. Omitting the results from a respondent who was not required to attend the career development workshop, 100% of the RPs agreed or strongly agreed that the workshop was a worthwhile component of the summer program. In the open-ended response section, four respondents noted that setting SMART goals was one of the most important things they learned from the workshop. One RP wrote, "The workshop was very informative and taught me the importance of networking and career profile-building. Not only was the information presented useful, but also it has long-reaching applications that I can use in the future, especially when preparing for a job in STEM. Furthermore, the sessions were always open to discussion and every question asked was always answered in a precise and clear manner." Perhaps most importantly, all students reported that they intend to pursue an advanced degree in a STEM discipline: 6 students reported they wish to pursue a PhD, and 3 a Masters. They all agreed or strongly agreed that doing research confirmed their field of interest and that their ability to set and achieve goals was better after the summer component. The 2015 REM runs through May 2016, so additional data will be gathered to assess medium and long-term outcomes that are described in Figure II.

## CONCLUSION AND DISCUSSIONS

The 2012-2015 NSF EFRI-REM program at CCNY has trained over 50 research participants (RPs) who are mostly from underrepresented groups, particularly individuals who are disabled, women, veterans and minorities. The diversity of the RPs provided great inspiration to everyone in every aspect of STEM education: from research relevance to

societal impact to student incentive to mutual understanding. The 8- or 10-week intensive summer research is very effective, and the follow-ups in the rest of the year have proved to be necessary to retain the RPs in STEM. We have not only provided exciting cross-disciplinary research opportunities in research and applications in assisting visually impaired people, but also created a formal model to support career development of the RPs at various stages of their studies and career development.

Here we would like to include a set of the lesson learned, the challenges we encountered, and recommendations for others who might be interested in adopting and adapting our model to their school environments.

- The pipeline structure enforced by daily individual mentoring and weekly group reviews works well and can scale up to a larger group of research participants spanning a large spectrum of their career development stages.
- Cross-disciplinary research for both skilled and beginners can be better implemented with a clear big picture of the research yet broad topic areas to choose, concrete technical mentoring but still flexibility in developing their own ideas.
- "Open door" office hours and a common room for all RPs to work enabled free exchange ideas and discussions to overcome some technical obstacles, created a team environment and research atmosphere.
- Weekly group meetings, esp. at the beginning of the program (each RP presents a proposed project with their mentor), in the middle (to report project progress weekly) and at the end (to present the achievements), ensures progress towards their SMART goals and trains RPs communication skills. Preparation for the publication at ERN and other conferences keep RPs engaged in research during & after summer.
- Weekly career workshops together with frequent career chat sessions integrated students' research experience with career mapping, resume writing, and portfolio development through individualized feed-back and peer support. This strengthened the RPs perceptions of how the research activities were tied to their larger career goals. Future REM programs could partner with their college or university's career development office to ensure such programming is sustainable.
- In retrospect, we wish we could have tutorials or mini-workshop for some technical topics, so we can address them once and for all at the beginning of the program: we have found that some RPs have encountered similar, if not the same, kind of obstacles.
- We have also found that RPs without other significant commitments (e.g., summer classes) would maximize their summer experience since research work is intense and has to be done in a short period of time. It would be more productive if we could help the RPs to schedule coursework during the academic year, instead of the summer research period.

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