AC 2010-581: INTEGRATING GRADUATE STUDENT RESEARCH INTO K-12 CLASSROOMS: A GK-12 FELLOWS PROJECT

Vikram Kapila, Polytechnic University

VIKRAM KAPILA is an Associate Professor of Mechanical Engineering at Polytechnic Institute of NYU, Brooklyn, NY, where he directs an NSF funded Web-Enabled Mechatronics and Process Control Remote Laboratory, an NSF funded Research Experience for Teachers Site in Mechatronics, and an NSF funded GK-12 Fellows project. He has held visiting positions with the Air Force Research Laboratories in Dayton, OH. His research interests are in cooperative control; distributed spacecraft formation control; linear/nonlinear control with applications to robust control, saturation control, and time-delay systems; closed-loop input shaping; spacecraft attitude control; mechatronics; and DSP/PC/microcontroller-based real-time control. Under Research Experience for Teachers Site and GK 12 Fellows programs, funded by the National Science Foundation, and the Central Brooklyn Robotics Initiative (CBRI), funded by the Independence Community Foundation, J.P. Morgan Chase Foundation, Motorola Foundation, and NY Space Grant Consortium, among others, he has conducted significant K-12 outreach to integrate engineering concepts in science classrooms and labs of several New York City public schools. He received Polytechnic's 2002 and 2008 Jacobs Excellence in Education Award and 2003 Distinguished Teacher Award. In 2004, he was selected for a three-year term as a Senior Faculty Fellow of NYU-Poly's Othmer Institute for Interdisciplinary Studies. His scholarly activities have included two edited books, 4 chapters in edited books, 1 book review, 40 journal articles, and 90 conference papers. Moreover, he has mentored 67 high school students, 86 high school teachers, 21 undergraduate summer interns, and 11 undergraduate capstone-design teams, and graduated seven M.S. and four Ph.D. students.

Magued Iskander, Polytechnic University

MAGUED ISKANDER is Associate Professor and Graduate Adviser of the Civil Engineering Department at Polytechnic Institute of NYU, Brooklyn, NY. Dr. Iskander is a recipient of NSF CAREER award, Chi Epsilon (Civil Engineering Honor Society) Metropolitan District James M. Robbins Excellence in Teaching Award, Polytechnic's Distinguished Teacher Award, and Polytechnic's Jacobs Excellence in Education Award. Dr. Iskander's research interests include Geotechnical modeling with transparent soils, foundation engineering, and urban geotechnology. He makes extenive uses of sensors and measurement systems in his research studies. Dr. Iskander has published 50 papers and supervised 6 doctoral students, 14 masters students, 6 undergraduate students, and 7 high school students.

Noel Kriftcher, Polytechnic University

NOEL KRIFTCHER is Executive Director of the Packard Center for Technology and Educational Alliances at Polytechnic Institute of NYU, Brooklyn, NY, where he also holds an appointment as Industry Professor of Humanities. At the Packard Center, he coordinates an extensive array of faculty development services, directs a consortium of colleges known as the Knowledge Workers Educational Alliance, and organizes varied hands-on scientific experiences and competitions for students in middle and high schools. He works closely with NSF-funded projects to connect them with the pre-college community and has won grants from the U.S. Dept. of Education, the NY State Education Department, and private foundations to improve access and opportunity for women and minorities for advanced study in science, mathematics, and technology. Before coming to Polytechnic, Dr. Kriftcher served as a teacher and administrator, then as principal of Seward Park High School in New York City, and as superintendent of the high schools in Brooklyn and Staten Island.

Integrating Graduate Student Research into K-12 Classrooms: A GK-12 Fellows Project

1. Introduction

In recent years, the importance of development of soft skills to the professional vitality of engineers has been recognized by, among others, the Accreditation Board for Engineering and Technology (ABET) via its criteria 2000.[1—3] Thus, in order to satisfy the ABET 2000 criteria, many undergraduate engineering programs in the U.S. have pursued various curricular strategies to provide opportunities for developing such skills in their graduates.[4—6] While the traditional academic preparation of graduate engineering students imparts to them a deep understanding of their disciplinary focus, formal efforts have rarely been devised to develop and enhance their soft skills. Yet, the marketplace demands graduate engineers who not only have the disciplinary expertise but can also communicate complex scientific and technical concepts effectively to a variety of stakeholders. For example, many graduate engineers are often called upon to educate others. While some may do this in a formal educational setting, many others do so informally, for example, to train co-workers or clients in the use of new devices or computer programs.

Using the model of National Science Foundation's Graduate Teaching Fellows in K-12 Education (GK-12) Program, Polytechnic Institute of New York University (NYU-Poly) is broadening the training and preparation of graduate engineering "Fellows" to allow them to become effective communicators and practitioners of their disciplines. Specifically, a summer workshop, conducted by a science education expert, introduces to Fellows fundamental concepts, tools, and strategies in teaching and learning so that they may develop effective teaching skills. Furthermore, the workshop develops Fellows' skills as mentors and leaders, and in communication, teamwork, and creativity. During the academic year, under the supervision of a partner teacher, Fellows serve as engineers-in-residence in local area elementary, middle, and high schools. The project allows the Fellows to connect their research with societal needs, become stronger scientists and engineers, and in the process, help improve teaching of science, technology, engineering, and math (STEM) courses in K-12 environment.

This paper provides an overview of the program's structure and activities. In addition, illustrative examples of Fellows' research and its classroom integration are given. Early results of project's impacts on three key constituencies, *viz.*, Fellows, students, and teachers, are also included.

2. Overview

Under the umbrella of a GK-12 Fellows program, NYU-Poly has entered into a partnership with 12 inner-city schools (five elementary schools: PS11, PS21, PS233, PS399, and PS636; four middle schools: MS113, IS318, IS383, and Urban Assembly Institute; and three high schools: Bedford Academy, Benjamin Banneker, and Boys and Girls) to broaden the education and training of graduate Fellows while providing technical literacy to teachers and enhancing the STEM educational experience of over 900 inner-city K-12 students each year. The demographics of project schools have socially diverse, economically disadvantaged, and underrepresented student and teacher bodies. For example, of the 1056 students currently supported, a large % are from groups historically underrepresented in STEM (93% minority, 49% female). Moreover, of the current 12 partner teachers, nine are female (African American-8, Hsipanic-1) and three male (African American-2, White-1). The project is led by two engineering faculty and a faculty member with extensive experience in educational leadership. Currently, a dozen graduate Fellows, mentored by eight faculty from all engineering departments, are enthusiastically participating in the project. The Fellows also exhibit gender diversity (three female and nine male) and ethnic diversity (two African American, one Hispanic, one Asian, and eight White). The main elements of the project are as follows.

Each spring, project leaders partner with faculty colleagues to invite graduate students from all engineering departments to participate in the project. In the spring semester, two open-house information sessions are held to inform potential applicants about the project. To receive consideration for the available positions, applicants must submit a formal application, official transcripts, curriculum vitae, two letters of recommendation, and an essay about their research plan and how they envision incorporating elements of their research to enhance the K-12 STEM education. Following a review of the applications, a team of project faculty and school teachers interview shortlisted candidates. These interviews seek to identify candidates who (i) have a deep content knowledge of their discipline; (ii) are comfortable in oral communication; (iii) can answer teachers' scientific and technical questions using everyday vocabulary, without relying of complex terminology of their discipline; and (iv) exhibit empathy. The interview team also seeks to indentify candidates who may have prior experience in working with the undergraduate and K-12 students in varied settings, e.g., summer camp, tutoring, outreach, mentoring, etc. The finalists are required to commit to a one year term for the project and receive tuition remission and $2,500 monthly stipend.

During the three summer months, Fellows learn about mechatronics[7, 8] and robotics by conducting numerous hands-on activities involving electric and electronic circuits, electromechanical devices, microntroller interfacing and programming, and LEGO robotics.[9] Moreover, they use the LEGO technology to develop sample lessons to illustrate grade-appropriate science and math concepts.

Prof. Catherine Milne, Associate Professor of Science Education from the Department of Teaching and Learning at the Steinhardt School of Culture, Education, and Human Development, conducts a three-day summer workshop to prepare Fellows for the classroom and enhance their communication, leadership, and teamwork skill. The workshop introduces to Fellows fundamental pedagogical concepts, tools, and strategies, e.g., lesson development, activities and materials for teaching, assessment, learning styles, and active learning. In order to develop and hone Fellows' communication skills, the workshop examines the nature of processes such as explanation, argument, contrasting, and predicting associated with communicating enthusiasm and understanding of their field of study. All Fellows are required to make ten-minute individual or team presentations geared towards explaining a scientific/technical concept to a lay audience. The instructor has adapted a rubric[10] for assessing the quality of scientific explanations using which she and project Fellows provide feedback to each presenter. Several teachers attend the last day of the pedagogy workshop to answer Fellows' questions and concerns about classroom expectations and orient the Fellows to realistic challenges they would face in the classroom. Two follow-up days to the workshop are conducted during the academic year, which concentrate on communication, leadership, and learning transfer and also allow the Fellows to bring their real-world class-room experience to bear on their pedagogical learning.

Next, Mr. Corbett Beder, a robotics master teacher with years of LEGO robotics experience conducts a three-day summer workshop where Fellows and teachers are introduced to LEGO robotics and the FIRST LEGO League (FLL) robotics competition. The participants also explore the potential for integrating LEGO-based activities in class and conduct collaborative activities under the guidance of the instructor. During the workshop period, the Fellows and teachers informally interact and network with one-another during the morning, lunch, and afternoon breaks. The matching of Fellows with teachers and schools also takes place during the workshop since the co-training experience allows the Fellows and teachers to become acquainted with one-another and form solid partnership for a yearlong professional relationship. Finally, all Fellows, who have not already taken the course *ME5643: Mechatronics*, are required to take it in the fall semester. This ensures that Fellows with diverse engineering background are all formally familiarized with the fundamentals of mechatronics.

After summer preparation, Fellows are deployed in schools where they partner with teachers to engage, mentor, and challenge students through mechatronics, robotics, and engineering activities, culminating in student's participation in a city-wide FLL robotics competition. These activities, organized around the FLL robotics competition and frequently embedded in the classroom, enable students to develop, apply, and enhance their STEM skills. Each fellow spends 10 hours per week at a school as a science resource, five hours conducting in-class activities and five hours mentoring the FLL robotics teams, and an additional five hours on NYU-Poly campus preparing for the school activities. The Fellows use their expertise in mechatronics, robotics, and engineering to enrich students' educational experience through robotics-based lessons. For example, Fellows have used mechatronics principles, hardware, and software to develop automated science lab apparatus to allow students to focus on inquiry-based, hands-on scientific explorations. Moreover, Fellows have developed and conducted robotics-based lessons to illustrate basic machines; science of electricity; physics concepts such as speed and torque; earth science topics such as water quality; math topics such as ratio and circumference; and programming. All Fellows develop and present a grade-appropriate overview of their graduate research to excite students about STEM careers. Fellows also serve as technical mentors to student teams participating in the FLL robotics competition. As mentors, Fellows use their engineering background to empower students to implement fundamental robot design principles, e.g., structural/mechanism designs, sensor selection and placement, gearing design, programming strategies, etc. Subject areas for classroom implementation differ for various grade levels and schools, and are selected in consultation with teachers.

To familiarize students with a real-world robotics competition, a practice tournament is conducted. Led by their Fellows, students collaborate to develop strategies to complete robot missions and to prepare research presentations. This is an important learning exercise for all participants, since few of them have had prior experience in such an event. It readily becomes apparent that what students learn surpasses mere mastery of building and programming robots to perform given tasks. They also learn applied math and science, improve their computer skills, engage in research, work effectively in groups, and become effective presenters.

Fellows perform numerous demonstrations and hands-on laboratory activities at their respective schools. These activities enhance offerings of science, math, and technology courses and are designed in collaboration with teachers to meet state performance standards. Moreover, Fellows perform the following types of activities: help students with their assignments during class, tutor and review for exam preparation, conduct tutorials, help students in preparing their science projects, work with science research students, etc. Fellows develop important relationships with students, helping them to understand what engineers do and encouraging them to consider career goals in STEM disciplines. Project activities provide students with opportunities to (i) visualize and practice STEM concepts that they otherwise find difficult to comprehend and (ii) learn tools and techniques that are used by STEM practitioners in real-world. Moreover, summer training and collaborative activities with Fellows help teachers become current with STEM content, technology, and career opportunities. The teachers also learn to use robotics as a vehicle to engage students through exciting hands-on activities. Finally, Fellows receive ample opportunities to improve their communication, team-building, and management skills, which prepare them for leadership roles in their careers and communities.

3. Integrated Research and Education Activities

The Fellows are conducting cutting-edge research in: marine systems, smart materials, image processing, protein engineering, biomolecular diagnostics, etc. Below we provide two illustrative examples of integrated research and education activities conducted by two Fellows, see[11] for additional examples.

Mechanical engineering doctoral candidate Nicole Abaid is conducting research in marine systems, including aquatic animals and underwater vehicles. Specifically, she is conducting theoretical and experimental research on the schooling behavior of golden shiner minnows. In a significant departure from the existing literature, where quantitative models of fish collective response are generally behavior-based, Nicole's modeling effort exploits a graph theoretic perspective wherein individual fish are represented as vertices on a graph and fish-to-fish interaction are represented as weighted or directed edges connecting vertices. The newly developed modeling framework has facilitated the application of consensus protocols to analyze spatio-temporal pattern formation of fish shoals due to engineered stimuli, such as light and sound. Nicole is also engaged in the design and development of a robotic fish that uses ionic polymer metal composites for propulsion. Specifically, she has collaborated with a team of graduate students to fabricate the hardware for several miniature robots and develop the software for robot's remote-controlled operation. The two streams of Nicole's research, *viz.*, live fish collective behavior and robotic fish, will be soon merged to investigate interactions among live and robotic fish to develop an improved understanding of traits such as leadership and decision making in animal groups.

Nicole is proactively integrating her research in eighth-grade science classes at an all-girls middle school. To teach concepts like force and pressure, she conducts experiments that use sensors and data acquisition devices similar to those used in her research. Nicole's marine systems research background enables her to use pertinent biological examples as illustrations to add significance to physical concepts being learned by her students. For example, when conducting a lesson on pressure, she describes physiological features of fish that allow them to sense pressure, and how the knowledge of pressure informs fish about their environment and their school neighbors. Nicole is also developing a marine biology and underwater robotics based fun-science exhibit for students at a local aquarium that includes a tour focused on underwater locomotion and an opportunity to operate the robotic fish developed in Nicole's research laboratory. This hands-on exploration will allow Nicole to impart to her students the spirit of empiricism that drives her research.

Electrical engineering doctoral candidate Pavel Khazron is conducting research in image processing. Specifically, he is developing an accurate statistical model to represent wavelet transform data arising in image processing applications. He has developed a new probability density function and corresponding Bayesian estimators for data corrupted by additive white Gaussian noise—an important problem in the area of signal enhancement and restoration. The newly developed model includes Gaussian and Laplace models as special cases. A motivation for this work is the need for efficient approximations to the Bessel K form density function, whose form and Bayesian estimators are not computationally efficient. Pavel's research contributes to the so-called Gaussian scale mixture family of densities, and is expected to be applicable to real-world image processing problems where the underlying data exhibit non-Gaussian behavior. For example, this work may find applications in improving the quality of degraded medical images such as PET scans.

Pavel uses his research in middle school robotics and computer classes to promote several disciplines within mechatronics. He teaches computer programming concepts using the NXT Mindstorms graphical programming language. He emphasizes the logic behind computer programs through flow diagrams—a tool that has allowed 6th and 7th grade robotics students to better grasp programming fundamentals and write more flexible programs for the FLL competition. He also uses programming languages such as PBasic[12] and MATLAB[13] in computer classes. For example, when introducing the binary number system, he engages the students in programming and testing a Morse code generator using the Basic Stamp microcontroller.[12] In a similar vain, through the interactive use of MATLAB software, natural images, and medical (PET) data, he teaches students about how real-world images are acquired, stored, and processed on a computer. Next, he extends this discussion to video processing, wherein students learn about different approaches to improving visual quality of a video that has been corrupted by noise. Pavel connects lessons drawn from these presentations to various applications of mechatronics like security systems, remote surveillance devices, and autonomous/robotic vehicles. He frequently uses demonstration resources from university's mechatronics laboratory to support discussions with his students. Previous demonstrations have included microcontroller-based robots with fixed behaviors, e.g., a six-legged walking robot, a room-navigating whisker robot, and a line-following robot.

4. Broadened Education and Training of Fellows

Through effective performance of their teaching, mentoring, and collaboration activities, Fellows are developing (i) a deeper understanding of STEM concepts; (ii) an ability to explore and recognize connections and relationships between different STEM concepts; (iii) an ability to practice and reflect on the process of knowledge building; (iv) an ability to review others' work and provide constructive criticism; and (v) an ability to revise and enhance their own work based on others' feedback. Development of these various abilities assists Fellows in their own research since every successful engineering research enterprise relies on deep understanding of fundamental underlying concepts; interconnections between different theories and tools; synthesis of new knowledge—often from first principles modeling, numerical validation, or experimental observations; critical review of the current state-of-the-art; and continuous improvement of one's own research results. Fellows' participation in developing hands-on mechatronics, robotics, and engineering activities for K-12 environment enhances their own understanding of the fundamentals of their research disciplines and provides them with an invaluable experience in the integration of theory, computation, hardware, and software elements. Moreover, Fellows' interactions with naturally inquisitive K-12 students foster Fellows' imagination and creativity in their own research. Finally, as delineated below, the project is providing numerous opportunities to broaden Fellows' communication, management, and teaching skills, which will serve them well throughout their professional careers.

4.1 Communication Skills

Written and Oral Communication Skills: In consultation with teachers and project faculty, Fellows develop and offer grade appropriate, hands-on, science and math activities and corresponding lessons. Selected lessons are written using the Activity Template of TeachEngineering.[14] Fellows review, critique, and edit each others' lessons in a peer-learning environment. Moreover, teachers evaluate language appropriateness of lessons for K-12 level. Each lesson explicitly identifies the state performance standards addressed by the proposed activity. Finally, Fellows deliver the developed lessons to youngsters. Illustrative examples of lessons that have been developed and taught and are under review for publication include: pendulum pandemonium, greenhouse gas monitoring, design of a trebuchet, flight simulator, conductivity of popular sports drinks, etc., see[11] for additional activities. Many of the developed lessons utilize LEGO technology, connect science and math concepts to engineering, and expose students to engineering analysis and design. Fellows also make frequent team-presentations about the project to various stakeholders, e.g., the university's Board of Trustees, corporate Foundations, and educational conferences.[15] One Fellow was invited to deliver the keynote speech at his partner school's 5th grade graduation. These activities are enabling Fellows to develop, practice, and hone their written and oral communication skills.

STEM Communication Skills: Fellows use theoretical, simulated, and experimental models to explain K-12 level STEM concepts. In addition, they use 2D and 3D graphs, spreadsheets, computer simulations, images and videos of physical objects/phenomena, and experimental hardware to communicate STEM concepts. For example, to teach robot structure construction and assembly of robot drive mechanism, Fellows often use Constructopedia.[16] These activities are enabling Fellows to develop, practice, and hone typical STEM communication skills employed by practicing scientists and engineers.

STEM Understanding Communication: Fellows learn to communicate complex STEM concepts in an effective manner to non-technical audiences. Specifically, Fellows learn to breakdown complex STEM concepts into easy to comprehend, basic building blocks. Next, using first principle laws from various STEM disciplines, Fellows communicate a fundamental understanding of the basic building blocks. Finally, the complex concepts are synthesized from the basic building blocks. Such an exercise in communicating complex STEM concepts (i) exposes Fellows to the process by which STEM practitioners construct new knowledge and (ii) imparts to Fellows a deeper understanding of science.[17] Recently, a Fellow and his advisor starred in and helped produce a short film about protein engineering directed at young audiences.

Communicating Applications of Science: Fellows draw upon their engineering education and graduate research to communicate the relevance of science and math concepts taught in K-12 grades to numerous real-world problems. For example, robotics is used to illustrate basic machines; science of electricity; physics concepts such as distance, speed, friction, motion, force, torque, and power; and math topics such as ratio, diameter, circumference, algebra, and geometry.

4.2 Management Skills

Team-building Skills: Fellows collaborate with one-another in a peer-learning environment to use laboratory lesson plans developed by others in their classrooms. Fellows partner with their teachers to implement laboratory lessons in their classrooms. Moreover, Fellows work with students to prepare for and compete in the FLL robotics competitions. Finally, Fellows work with research mentors toward their research assignments. To perform successfully in these activities, Fellows are developing and mastering team-building skills.

Leadership Skills: Fellows serve as STEM role-models to students and as technical advisors to teachers in K-12 classrooms. In addition, Fellows provide technical mentoring to FLL robotics teams. Often, Fellows are called upon to serve as judges for math, science, and robotics events. Finally, Fellows present their technical research results and outcomes of their educational outreach activities at technical and educational conferences. These activities enable Fellows to develop, practice, and hone their leadership skills. The project thrusts Fellows in an unfamiliar environment with its own unique culture. This challenges Fellows to learn both the individuals involved and the environment, respectfully, adapt, and assert their knowledge, skills, and abilities. All of these experiences will be assets to Fellows in the workplace and their communities in the future.

Project Management: To successfully manage their academic workload, research projects, and GK-12 responsibilities, it is essential for Fellows to develop good planning and time management strategies. Moreover, Fellows' activities entail interactions with university personnel, teachers, students, etc., which allow them to develop people skills and social aptitude.

4.3 Teaching Skills

Through activities such as curriculum review, laboratory development, lesson planning, standards correlation, classroom presentation, teacher feedback, and student mentoring, Fellows are developing teaching skills that will serve them in their professional careers. For example, in a non-academic professional career, the GK-12 teaching experience will allow fellows to (i) better explain to their supervisors their work and tools and techniques used; (ii) explain to their peers and juniors work assignments; and (iii) interact with technical and non-technical members of a client's team. Finally, teaching requires adaptability in an often unpredictable classroom environment; thus preparing Fellows to become adaptable to the evolving globally competitive economy.

5. Evaluation Results

Project evaluation focuses on determining project's impact on each participating group. For Fellows, project's impact on their leadership and team building skills and their ability to explain technical material to non-technical audiences is ascertained. For students, project's impact on their interest in STEM studies and careers, as well as their academic motivation and achievement is examined. For teachers, project's impact on their teaching techniques, confidence, motivation, and technology literacy is investigated. Under the leadership of Dr. Robert Tobias, Director of the Center for Research on Teaching and Learning at the Steinhardt School, an external evaluation team: designs and administers targeted surveys to each group; performs observations at summer workshops, FLL contests, classrooms, and meetings; and conducts focus groups to qualitatively evaluate project's effectiveness. Following are some highlights from the recent evaluation of the project.

According to external evaluators' observation report of the pedagogy workshop, "Fellows were introduced to the basic ideas around the teaching and learning of STEM. Several returning Fellows indicated that the workshop of summer 2009 was an improvement over the workshop of summer 2008, which was conducted by a different pedagogy expert. Moreover, 90% of the Fellows reported that the workshop introduced them to specific pedagogical strategies associated with the teaching and learning of STEM topics and that they would be able to use what they learned in the workshop at their assigned schools. However, only 50% of the Fellows believed that the workshop helped them examine the role of technology in teaching and learning of STEM topics." From their observations at the Fellow-teacher LEGO co-training workshop, the external evaluators reported that "as the workshop instructor guided the Fellows and teachers to work together on various LEGO robotics projects, he asked them to share their thinking around particular designs and explain what they learned in building and programming their robots. From these conversations, the instructor provided guidance on how to help students overcome the problems that they may experience and become more proficient in robotics, e.g., using worksheets to keep track of what various sensors do and how to work with them. Moreover, three Fellows demonstrated the use of LEGO technology in conducting hands-on science and math lessons. The Fellows and teachers agreed that the co-training workshop allowed them to build a rapport and served as a team building exercise."

Survey responses from Fellows reveal that a large % of Fellows indicated an increase in their ability to: plan STEM lessons (100% of Fellows); teach STEM subjects to students (88% of Fellows); explain STEM concepts to non-technical audiences (88% of Fellows); be an effective leader (88% of Fellows); work in a team (88% of Fellows); give oral presentations (75% of Fellows); manage time (75% of Fellows); and communicate STEM concepts in writing (75% of Fellows). Moreover, Fellows reported that participation in the project influenced them in following additional ways: gain respect for young peoples' capacity to work as a team independent of an adult (88% of Fellows); acquire an understanding of what young people can accomplish when given the chance (88% of Fellows); ability to connect applications of science and technology to real-world setting (75% of Fellows); and increased knowledge of current science and technology (75% of Fellows). When asked by the external evaluators to list specific ways in which they benefitted from participating in the project, several Fellows indicated that they found teaching and working with students to be gratifying.

The external evaluators reported the findings of their school visits and interviews with Fellows and their partner teachers as follows. "Fellows are able to integrate their research into their work with teachers and students to the mutual benefit of the three constituent groups in this triadic relationship. The teachers strongly support the Fellows' in-class activities and provide consistent feedback to the Fellows. The effect of the symbiotic connection between the Fellows and the teachers is illustrated by the Fellows who indicated that the in-class and after-school time spent with the teachers and students are constructive in helping them develop their instructional practices. The Fellows have gained an appreciation for the rigors and demands of teaching as well as skill and confidence in their teaching."

Survey responses from 228 students indicated that working with Fellows: helped them learn more about STEM (82% of students); increased their interest in STEM (77% of students); and helped them gain a better understanding of how STEM fields are used to solve real-world problems (73% of students). Moreover, 89% of the students enjoyed working with the Fellows; 80% of the students rated their experience working with the Fellows as good or excellent; 80% of the students saw the Fellows as good role models; and 79% of students reported that Fellows were creative in helping students understand lessons. Participation in the project increased students' skills to: listen and respond to other people's suggestions and concerns (83% of students); gather and analyze information from different sources (72% of students); learn new ways of thinking or acting from other people (72% of students); and solve unexpected problems or find new or better ways to do things (69% of students).

The external evaluators reported the findings of their observation visits to schools as follows. “Students in each of the after-school component of the program were highly engaged in preparation for the robotics tournaments. Under the guidance of the Fellows and their teacher-coaches, they actively participated in programming and constructing the robots and doing research for the tournament presentations. It was clear that in addition to learning problem solving, STEM skills and concepts, and the application of theory to practice; they were developing team-building and relationship skills. The students were found to be engaged in a variety of tasks. For example, at one site, two students worked with the Fellow to program and test missions; another five students wrote and rehearsed their presentation with their teacher; and two other students created team banners. While the tasks were somewhat compartmentalized, most of the students had the opportunity to perform a variety of functions on their team. Students were engaged academically, socially, and emotionally in the project and students’ families were supportive and enthusiastic.”

Survey responses from project teachers reveal that the Fellows supported them in a multitude of ways, such as: designed labs or hands-on activities (100% of teachers); planned or co-planned math and science lessons (100% of teachers); demonstrated key math and science concepts using robots, sensors, or other technology (100% of teachers); taught critical thinking/problem solving skills (80% of teachers); worked one-on-one with students or small groups (80% of teachers); and prepared students for exams in math and science (60% of teachers). The teachers reported following impacts from their partnership with the Fellows: use newly learned material in future teaching (88% of teachers); working with a Fellow was a beneficial experience (88% of teachers); enhanced use of inquiry-based instruction in classroom (75% of teachers); increased ability to use robotics in teaching (75% of teachers); exposure to new content in math, science, or technology (63% of teachers); Fellows’ lessons fit well into math or science curriculum (63% of teachers); and Fellow was creative in helping teach math and science concepts (63% of teachers).

The external evaluators offered following qualitative remarks on project’s impact on teachers. “When discussing the specific benefits they received from working with the Fellows, teachers indicated that the Fellows helped integrate technology into their classroom and shape their curriculum. One teacher stated that working with a Fellow reignited her desire to expand curriculum. In addition to impacting teachers’ STEM knowledge and capacity to use this knowledge in their classrooms, the project helped shape the way teachers viewed their students. Several teachers indicated that the project raised their expectations for the levels of skill and knowledge in STEM that pupils can attain. The project enabled them to challenge their students’ research, problem-solving, and critical-thinking skills. One teacher expressed amazement that the students responded like sponges soaking up these higher-order concepts and skills.”

Finally, the external evaluators reported obtaining "important information about the functioning of the program by observing FLL competitions. Specifically, at the Brooklyn qualifier round, the Fellows, teachers, and students were found working together in a variety of ways, but perhaps most importantly, the students were found to be well prepared and self directed. For example, when one team's robot missed a turn in one competition round, the two students tasked with the robot construction and program took their robot to a practice course and tested the particular failed maneuver several times. During that time they talked about whether their robot was positioned properly or if they needed to adjust the motor rotations. They ultimately reprogrammed the robot and tested it again until they got the desired result. The entire time, the students' teacher and Fellow were in the room. However, the students did not need to seek out their help; rather they were equipped to solve the problems on their own. Nine of the 12 FLL teams currently mentored by the Fellows won various awards and qualified for nine of the 19 Brooklyn slots at the New York City FLL competition."

6. Conclusion

Under the umbrella of a GK-12 Fellows program, funded by the National Science Foundation and several philanthropic and corporate foundations, a higher education institution is collaborating with 12 inner-city schools, a science education expert, a robotics master teacher, and faculty from all engineering departments to broaden the education and training of graduate students. By having graduate students with STEM expertise work closely with students and teachers is generating intergenerational learning, bringing relevant technical knowledge to classrooms, and exposing students to career possibilities. For students who lack exposure to STEM fields, careers, and role models in their own schools, families, and communities, project's African American, Hispanic, and female Fellows illustrate that academic achievement and professional excellence is not confined to only one gender or certain races. Finally, the partnership between a research university and K-12 schools in an inner-city offers a profound investment in the education of young people when they are impressionable and potentially at-risk.

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