The Center for Pre-College Programs

A History and Legacy of STEM Education at NJIT

As Told by Howard Kimmel

NJIT
New Jersey Institute of Technology

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FOREWORD

By Joel S. Bloom
President
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Many years ago, I was drawn to New Jersey Institute of Technology (NJIT) because of its very important mission, and I have been fortunate to have spent the last 27 years here doing my part to help assure the successful achievement of that mission. One aspect of NJIT that was particularly attractive to me from the outset was NJIT's commitment to pre-college education.

Prior to my employment at NJIT, I was the assistant commissioner for K-12 education in the State of New Jersey, where I helped launch New Jersey's first high-tech high school in Hackensack, N.J., the Bergen Academy. So, the idea of being involved with a university that was doing innovative work in building the STEM pipeline was quite appealing. Back in the 1990s, NJIT's Center for Pre-College Programs was truly progressive in identifying populations that were underrepresented among students in the science and technology disciplines and in involving tenured faculty in the effort to address those shortfalls.

In fact, the Center for Pre-College Programs was led then by a tenured member of the chemical engineering faculty, Howard Kimmel. A hard-driving visionary, Dr. Kimmel maintained an unabashed belief that the center could help many students from the greater Newark area complete high school and enter post-secondary education institutions by providing them with exposure to and proficiency in areas of learning that they might not otherwise be able to access. Dr. Kimmel aggressively pursued faculty, staff, funding and partnerships in support of this goal and was able to prove that experiencing "fun" engineering programs during the summer would result in enhanced student success.

Over time, Dr. Kimmel and his colleagues became immersed in the development of a curriculum that today would be described as STEM-based and marked by hands-on pedagogy as well as student outcomes assessment. Their success has been well documented, and thousands of students have benefited from their commitment as well as the efforts of the Center for Pre-College Programs.

Today, NJIT's Center for Pre-College Programs works annually with 3,000 pre-college students who are predominantly underrepresented females and minorities from the greater Newark area and northern New Jersey. Of those students, well over 200 from underrepresented populations enroll as undergraduates at NJIT each fall and pursue STEM professions. The positive impact of the Center for Pre-College Programs, Dr. Kimmel and the many faculty and staff members who have helped the center pursue its mission cannot be overstated.

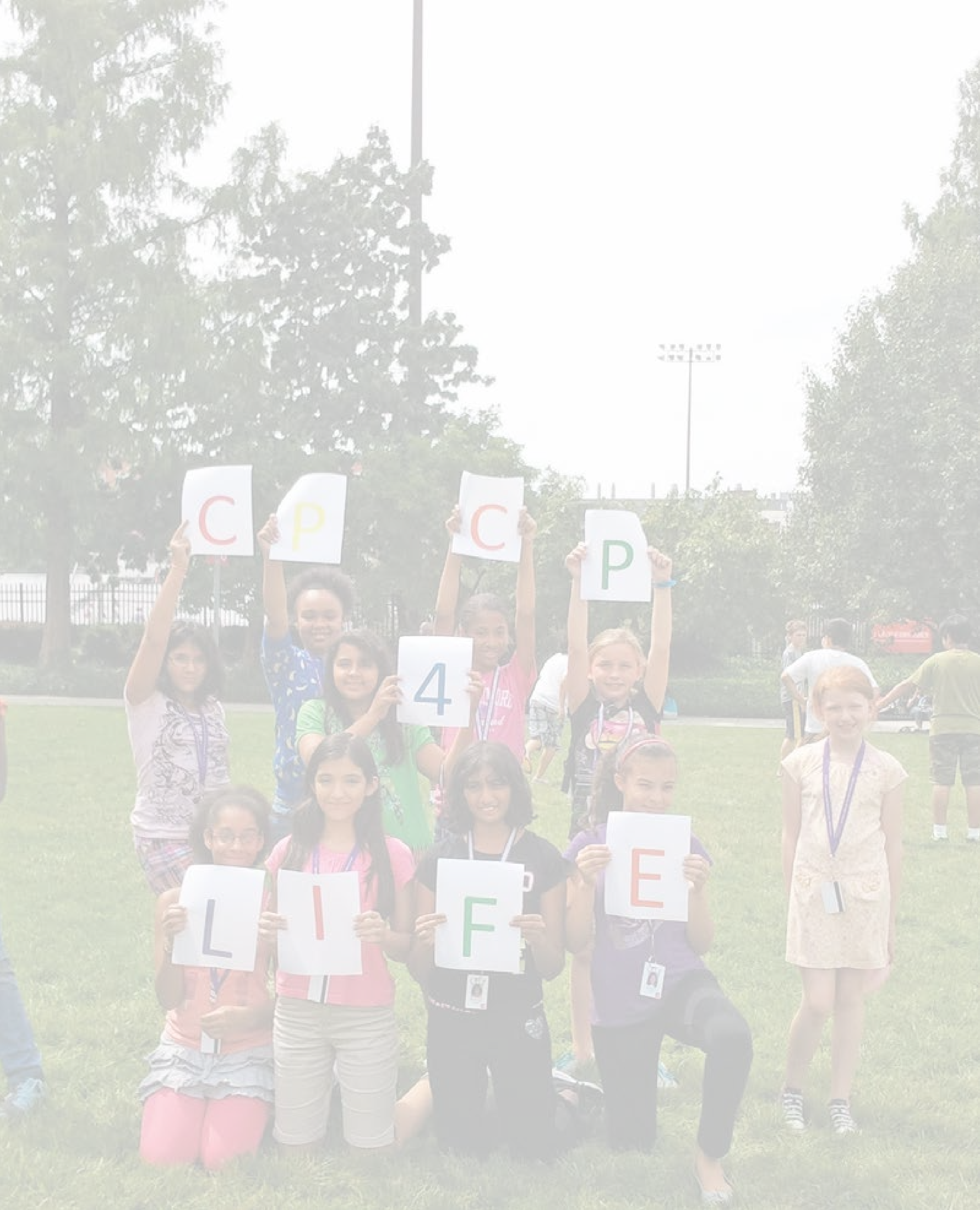
Chapter 1
The Beginning

Howard Kimmel arrived at Newark College of Engineering (NCE) (which later became New Jersey Institute of Technology in 1974) in 1966 as an assistant professor of chemistry in a joint Department of Chemical Engineering and Chemistry formed in 1966. His expectation at that time was to focus on becoming a facilitator of learning for undergraduate and graduate students, while pursuing scholarship through an active research program. He retired from New Jersey Institute of Technology (NJIT) in August 2012 after 46 years as professor of chemical engineering with a completely different focus – reform in K-12 education.

The change in focus began in 1974. In 1970, the first pre-college student program was implemented with funding from the National Science Foundation (NSF). The program, Urban Engineering, co-directed by Harold Deutschman and Su-Ling Cheng of the Department of Civil Engineering, was intended for Newark high school students. In 1974, grants were received from Exxon and General Electric, in addition to funding from NSF, to expand the program from 40 to 80 students by adding subjects (energy and environmental issues) and extending it to the junior high school level. John Droughton and Dr. Kimmel were invited to become co-project directors of the program along with Dr. Cheng and Dr. Deutschman. While Dr. Cheng and Dr. Deutschman continued their responsibility for the urban planning and transportation components, respectively, Dr. Droughton taught the energy component while Dr. Kimmel taught the environmental-issues component. Dr. Kimmel found this to be a rewarding and enriching experience. In 1975, he became principal investigator for a grant awarded by the NSF for secondary school teachers on Energy and Environmental Technology. On this grant he was joined by Professor Reginald Tomkins, Professor Manny Perez and Professor Achille Capecelatro.

Working with these junior high and high school students and teachers had a profound effect on Dr. Kimmel, and led to the recognition that his career path and interests had changed. One experience that remains in his memory occurred during a field trip in 1975 to the Exxon refinery in Linden, N.J. This was the time of the first major gas shortage in the United States. After the tour of the facilities, the students gathered in an auditorium for a question and answer session with Exxon employees. It should have been a discussion led by an experienced Exxon employee. Instead, the company sent a relatively new public relations person to answer the students' questions. The students impressed Dr. Kimmel with their questions that showed a great deal of thought and maturity for their ages. He almost felt sorry for the Exxon employee, who must have been embarrassed as he was unable to respond to most of the questions asked by the students.

Entering the world of K-12 education caused Dr. Kimmel to rethink his original focus on college-level teaching and scientific research. He came to the conclusion that while there were a great many faculty actively pursuing significant research studies, there were very few with the interest to focus on the needs of K-12 students and teachers. And, in his very limited time of involvement, he found that he had developed a great interest, satisfaction and sense of accomplishment in his work with pre-college students and teachers. Their needs in science, math and engineering were great. It was then that he made the decision to leave his technical research activities so that he could devote his time and energy to the pre-college sector, while continuing his other responsibilities as a member of the university faculty. So, he devoted the next 35 years to pre-college programs. He never looked back on this career change.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Chapter 2

The Center for Pre-College Programs

After much discussion between Dr. Deutschman and Dr. Kimmel and with University Advancement regarding a stable source of funding for pre-college programs, Drs. Deutschman and Kimmel went to meet with Gerald O'Loughlin, a vice president with New Jersey Bell, in his office in downtown Newark. He made the suggestion that if NJIT was to establish an entity under which pre-college programs would be housed, he would volunteer to take a lead role to help secure additional funding for the programs. What followed was the creation of the Center for Pre-College Programs (CPCP) by NJIT's Board of Overseers and the university in 1979. Drs. Deutschman and Kimmel were asked to serve as the co-directors of the center. In addition, the Board of Overseers established an Advisory Board to the Center for Pre-College Programs to provide for representation by business and industry as well as educators from public and private secondary schools. The Advisory Board was headed by a chairman and served by a secretary, both of whom were selected from outside representatives. In 1983, the Advisory Board voted to establish three additional leadership positions to chair the committees for program planning and evaluation, policies and procedures, and fundraising. O'Loughlin was named as the first chairman of the Advisory Board, and Michael Lione Jr., also at New Jersey Bell, was named the vice chairman. NJIT and the Foundation at NJIT were represented on the Advisory Board by memberships of the director(s) of the center, two vice presidents of the Foundation and the director of the Educational Opportunity Program. Rosa Cano accepted the position of assistant director of the center, becoming the first full-time professional staff person. Soon thereafter, Diana Muldrow joined the center as a coordinator.

In 1998, O'Loughlin and Lione Jr. retired from New Jersey Bell and from the Advisory Board. Michael Bober of ExxonMobil was elected chair and William Lewis, retired president of Sigma Management Associates and councilman for the city of Orange, was elected vice chair. Both Bober and Lewis are NJIT alums. Lewis also established a scholarship fund through the Foundation at NJIT for students enrolling at NJIT who graduated from Orange High School. Now deceased, Lewis continued to make donations to the fund since its establishment in 2000.

Through its Center for Pre-College Programs, NJIT shares the state's vision for strong STEM (science, technology, engineering and mathematics) education throughout New Jersey and applies the knowledge and resources of NJIT, in partnership with teachers, schools and other stakeholders, to help make this vision a reality. Since its establishment, the center has undergone several fundamental transformations of its identity and goals. It has evolved from a locally focused center working with 40 high school students from Newark schools into a comprehensive academic service department at NJIT serving a widening geographical audience of over 30,000 students, teachers, parents and educational professionals from grades K-16. This expansion includes the translation of its initiatives to implement K-12 content standards in guiding university faculty in meeting accreditation requirements for undergraduate programs.

The Center for Pre-College Programs has become a driving force in providing increasing access to scientific and technological fields to all students. The center's programs' academic curricula are aligned with state and national standards. The center's models for success bring academic opportunities to children in the STEM areas, as well as teacher training, curriculum reform, assessment methodologies, development and dissemination of resource materials, and standards-based classroom lessons and practices for teachers to integrate into their own classroom practices and school's academic curriculum.

Effective 2015, the vision statement for the center became: Inspiring young minds for college access and success in science, technology, engineering and mathematics (STEM). The current goals and objectives can be found in Appendix A.

The comprehensive nature of the center is an outgrowth of several groundbreaking initiatives. These initiatives include:

- Electronic Communications for Teacher Professional Development: Creation of a Professional Learning Community.
- Women in Engineering and Technology Initiative.
- STEM.
- Dual Enrollment.

The Pre-College story is being told in chapters. Connections between topics in different chapters, as well as references to previous discussions, should become apparent.

Chapter 3

Electronic Communications for Teacher Professional Development: Creation of a Professional Learning Community

The internet evolved during the 1980s, established as a technology supporting a broad community of university researchers, developers and scholars, and the World Wide Web was developed in the early 1990s. In 1994, a National Research Council report, sponsored by the National Science Foundation (NSF) and titled "Realizing the Information Future: The Internet and Beyond," was released.

Thus, the utilization of a computerized conferencing system (The Electronic Information Exchange System (EIES), developed by Murray Turoff, professor of computer science at NJIT) in 1984 as a tool for professional development of a community of New Jersey middle school teachers was a groundbreaking initiative in K-12 education. Supported by a grant from the New Jersey Department of Higher Education, Mark O'Shea, professor of science education at Fairleigh Dickinson University (FDU), and Dr. Kimmel brought together a dedicated group of middle school/junior high school science teachers from 25 schools in northern and central New Jersey to form a professional learning community, in an effort to build their professional repertoire of student-centered, investigative lessons. The development and modification of curriculum was no longer a local isolated event. Electronic conferencing initiated interdistrict cooperation and participation in curriculum, resource and lesson development in a way that was not possible by traditional means.

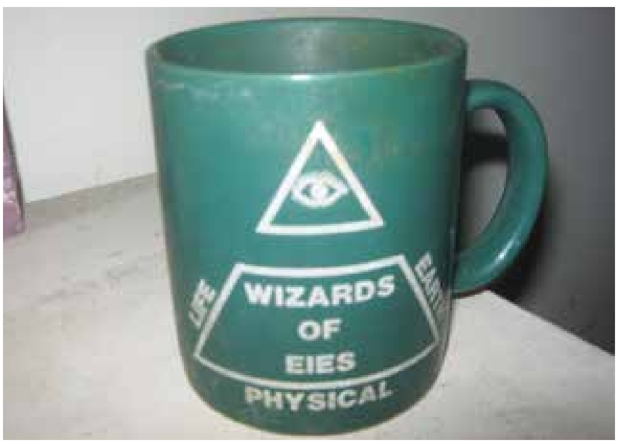
In the first year, with authorization from the American Association for the Advancement of Science (AAAS), these teachers began a professional development program for the improvement of their science curriculum and science teaching, focused on AAAS curriculum materials, which continued to meet the needs of the teachers, who controlled the destiny of the professional development program and their students.

In the following years of the program, the teachers focused their studies on an interdisciplinary theme central to the future of New Jersey. Selected themes lent themselves to investigations through the geological, biological and physical sciences and New Jersey's environmental condition, and were conducive to extended investigations by students regardless of their specific science course. Teachers wished to add activities to their teaching repertoire that applied to their discipline.

During the 1987-1988 school year, the theme was "New Jersey Coastal Environmental Education." The goal was to provide six weeks of curriculum resources relating the theme to each of the traditional disciplines taught in junior high and middle schools (physical, life and earth sciences). In collaboration with the New Jersey Marine Sciences Consortium (NJMSC), the start of study and curriculum development by the teachers involved spending a week in residence at the Seaville field site of the NJMSC. This residential week provided a common linking experience for the professional development and electronic conferencing that followed. With guidance from the NJMSC staff, the teachers spent each day learning about the environment of the Jersey shore and the ocean, and how it can be integrated into their physical sciences, life sciences and earth sciences curriculums.

At the residential program at Seaville, 25 middle-aged men and women professionals spent five days in a World War II army barracks. This provided them with a bonding experience probably like no other, either before or after this event. It was a bonding that led to a very close professional learning community. The teachers even came up with a name for their community: The Wizards of EIES. The teachers were somewhat annoyed that neither Dr. O'Shea nor Dr. Kimmel spent that time in the barracks with them. Dr. Kimmel and his family were on vacation that week. While Dr. O'Shea was there for the field experiences, he spent the evenings with his family at a nearby motel, a bit more luxurious than the barracks. Dr. Kimmel arrived in Seaville on the last day of the residential program to find a sign on the dining room of the facility posted by the teachers that read "Howard's Go-Go Bar – Girls-Girls-Girls." This was a very clear indication of the bonding that occurred among those teachers. And in the end, the teachers greatly enjoyed the time at the shore and felt that it was a wonderful learning experience for them.

The professional development program consisted of several one-day workshops, about five to six weeks apart during the school year, and a summer program, held either at NJIT, FDU or at field sites. Between workshops, teachers communicated with each other through EIES, the electronic conferencing system housed at NJIT. Teachers were able to connect from their school or home microcomputer hooked up to a telephone line by a modem. Through EIES, teachers were able to ask questions of each other and of higher-education faculty, and refer student questions to each other and to students at other schools. In addition to electronic messaging, EIES featured a "notebook" that was designed for joint composition of documents. The availability of the notebook allowed teachers to "virtually" draft and co-author two volumes of marine science classroom activities – for example, one for the physical sciences and one for the life sciences. An additional feature was the "conferencing" capabilities that maintained a permanent and modifiable transcript of the proceedings, and allowed teachers to receive and transmit lab activities, demonstrations, test and quiz questions, and any other print resource that contributed to a teaching repertoire of all members of this electronic professional learning community. As one participating teacher commented, "Through these workshops and field exercises, I've gathered enough ideas and activities for a lifetime."



Teachers taking part in the NJMSC dubbed their professional learning community The Wizards of EIES and designed this coffee mug.

An example of an environmental project that teachers and their students became involved in was an acid rain deposition measurement project for which they collected rain and snow samples and reported the pH of the samples. Results were compared for different school locations. All reported data and collected results were submitted and discussed on the conferencing system.

Another project that demonstrated the interactions among middle school students from different schools was the Big Gulp Project, in which students wanted to determine how much water a middle school student drinks from a school fountain. The idea for the project came from a concern about contaminants in the drinking water and how they might affect people's health. A scientific method was sought to measure the volume of a mouth full of water, called a gulp, and then find out how many gulps were consumed in an average week. Students identified a problem, brainstormed different possible measurement methods, and finally agreed on a method that was simple and inexpensive, and worked! Students from one school in New Jersey collected the data from participating schools, and then analyzed it. They included a statistical analysis to ensure validity of the data, and then discussed the results online. In 2016, there were concerns of lead contamination in schools in Newark, N.J., and Flint, Mich.

The electronic conferencing effort provided Dr. Kimmel with the opportunity to submit a proposed cooperative project that could be carried out between U.S. and United Kingdom (U.K.) educators. As a result, he was one of 10 U.S. educators to be invited to participate in the British-U.S. collaboration: the ASE-NSTA Cooperative Seminar in Washington, D.C. in March 1987. ASE is the U.K. Association for Science Education and NSTA is the U.S. National Science Teachers Association. Educators from both sides of the Atlantic were invited to make presentations on topics that could lead to collaborations of representatives from both countries. His presentation was "An Inter-School Scientific Project: A Nontraditional Collaboration Between Geographically Dispersed Sites."

At the seminar, Dr. Kimmel was teamed with two science educators from the U.K: Neil McKenzie of Fulwood High School, Preston, Lancasshire, and Jim Teasdale of the Wirral Schools Tech Centre in Wallasey, Merseyside. Together they prepared a proposal to initiate an investigative student project involving a collaboration of secondary school students from the U.S. and U.K. that applied science concepts to a real-world problem. The collaboration included collecting, analyzing, sharing and comparing data and findings from both sides of the Atlantic that would enable the students to understand that many real-world problems are global in nature and would require collaborative solutions. The planning and operation of the project by the U.S. team (which also included teachers from the EIES project) was facilitated by the electronic conferencing system. The proposed project was used to demonstrate how the use of electronic communication could minimize the barriers of classroom walls and geography to bring together students of two different countries, separated physically by the Atlantic Ocean, into a single "electronic classroom." The project was carried out over a period of 20 months, leading to a presentation of the project and its results by the three educators at the joint seminar, "International Links," at the annual meeting of ASE in Birmingham, England, in January 1989.

In 1988, Dr. Kimmel contacted Donald Young of the Curriculum Research and Development Group at the University of Hawaii (UH) to ascertain his and the university's interest in the joint development of a proposal to the Hitachi Foundation for a study of international education telecommunications. His response was "absolutely!" Accordingly, a collaborative proposal was submitted and a grant from the Hitachi Foundation led to the creation of The International Network for Education in Science and Technology Project (INEST), which brought together the resources of NJIT and UH to link schools in New Jersey and Hawaii with schools in other U.S. states (Maine, Minnesota and North Carolina), Hungary, Japan, Russia and Singapore, all of whom were or would be using the Foundational Approaches in Science Teaching (FAST) program.

NJIT and UH collaborated to design INEST to develop both an international communications network of middle school and junior high school teachers and their students and a cross-cultural curriculum that would address global environmental concerns, such as weather patterns, acid rain, soil analysis and ozone depletion. The project provided the opportunity for students in geographically dispersed locations to share scientific data – planning, measurement decisions, data-collection experiences and analytical methodologies – all taking place online. Videotapes of classes were exchanged to provide a visual image of the different environments. Data were collected during the same periods of time, uploaded into the EIES network, and compared by classes in diverse areas. Data collection was coordinated by the primary sites at NJIT and UH.

INEST was meant to provide an outlet for the students at different locations to share ideas and concerns of a regional and global nature that would be appropriate for collaborative investigations among the students and their teachers across the country and around the world. Initially, a newsletter was published twice during the school year as the vehicle for sharing ideas among the students. The newsletter allowed the students to create their own contribution to some environmental concern. The youngsters were encouraged to think globally, which allowed for an exchange among the culturally diverse participants at the different sites. The exploration of collaborative activities was diverse and initially included such topics as acid rain, water resource management, solid waste management and global warming (which has now become climate change). All of these topics had and still have international implications and were appropriate for this project.

For a common task carried out on a regular basis throughout the school year, each class reported climatic measures for a specific date each month, and also provided information on the different geographical locations in the network, including:

– High and low temperatures (and times they occur).
– Times of sunrise and sunset and number of hours of daylight.
– Barometric pressure and time recorded.
– Wind speed and direction.
– Type and amount of participation, if any.
– Special climatic happenings, e.g., fog, hurricanes, blizzards.

The weather data provided students the opportunity to collate, analyze and compare the collected information, and discuss the differences between the different locations. For global warming, as an example, students researched data from the past to determine if the data supported trends of global warming and determine if global warming was indeed a real environmental concern. The reporting of climatic measures brought in the subjects of astronomy and geography as areas of study, since there is a geographical distribution of the participants across time zones and the international time line. Students became aware of comparisons of Eastern time with Hawaiian time or Japanese time, for example.

The Force in the Forest project spotlighted the world's vanishing rain forests, a topic that students in the U.S. rarely, if ever, get to explore. This provided New Jersey teachers and students the opportunity to study the subject by communicating with students and teachers who are living near rain forests. In addition to Hawaii, a teacher from a small island in the Pacific was a participant in this project. Teachers from a participating New Jersey school district obtained funds to travel to Hawaii's rain forest.

One unusual project was the exploration of the applicability of physical science in the teaching of environmental topics. Students created Rube Goldberg devices to demonstrate and explain the cycles that existed in the biosphere, while illustrating a particular environmental topic or problem. At the end of the year, students presented their projects as "working solutions" for environmental problems. Selected topics included the nitrogen cycle, water cycle, acid rain, marine science, the rain forest, water pollution and solid waste reduction. The final devices were recorded on videotape and shared among all the sites of the network.

INEST provided teachers with stimulating experiences in professional development and curriculum improvement, while students received an exciting cultural exchange activity, developed enhancements in their mathematical and communications skills, and had direct experiences in global issues that involved science and technology.

Another project that focused on the environment was The Jersey Coast Explorers, a spinoff of the Science Curriculum Improvement Project funded by the New Jersey Department of Higher Education. The program provided the opportunity for three classes of students (two seventh-grade classes and one sixth-grade class) from two Newark schools to have field experiences that enhanced their classroom experiences in the study of marine science. Two of the classes were taught by teachers in the project. The Jersey Coast Explorers was designed to give the students an appreciation of New Jersey's coastal and marine resources and what could be done to conserve them. The ocean beaches of Sandy Hook were the setting for the field experiences, including investigating a salt marsh, measuring waves and currents of the ocean tide, and sailing on an Oceanographic research vessel, provided for the students and teachers by NJMSC specialists. The classroom-based portion of the program was facilitated by NJIT faculty.

Students express their admiration for the Center for Pre-College Programs while on the NJIT campus.

Chapter 4
Women in Engineering Programs

Although the number of females entering college engineering programs and engineering careers has increased over the past 30 years, there still appears to be a gender gap among those entering the engineering profession. At the start of the 1980s, there was a great lack of females pursuing engineering careers. At the elementary-grade levels, girls seem to do as well as boys in science and math. However, female students appear to start losing interest in science and math in their early teenage years. And the difference between boys and girls is not academic achievement, but rather their attitude toward such fields. Completing the appropriate high school courses in science and math serves as a gateway to a college degree and career in engineering.

Recognizing this requisite to pursuing an engineering career, NJIT in 1980 sought ways to attract more females into engineering. The provost approached Drs. Deutschman and Kimmel with a proposition: NJIT would provide the seed money if they were to develop and implement a summer program for females. Thus, in 1981, the FEMME (Female in Engineering, Methods, Motivation, Experiences) program for post-ninth grade female students was born.

Directed by Dana Levine, lecturer in the Department of Chemical Engineering and Chemistry at NJIT, FEMME was a four-week summer program designed to give academically talented ninth-grade girls a taste of the engineering disciplines. The program provided exciting and enriching experiences, such as actively participating in laboratory experiments and projects, listening to guest speakers (female engineers and scientists), taking field trips to industrial and scientific facilities, and receiving career counseling. From participation in this program, female students were able to gain confidence in themselves and their abilities, and were encouraged to obtain the preparation in high school to pursue courses of study leading to degrees and careers in engineering or science, see that a technical degree can be stimulating and intellectually rewarding, and get exposure to the great number and variety of career opportunities available to them in engineering and the sciences.

The four-week program provided a nontraditional exposure to the relevant subject areas, which high school curricula at the time were not equipped for or capable of delivering. As an example of an experiment/project, students designed and built a working burglar alarm, complete with bell and photoelectric eye. They watched as a guest speaker, a woman electrical engineer from Bell Labs, demonstrated memory storage in computers and how a chip was made. Field trips included a tour of a refinery to learn how petroleum is distilled and cracked into gasoline, the opportunity to stand on the top of a steam boiler of a generating station to learn how fossil fuel is converted into electricity, and a tour of a cosmetics plant to view the manufacturing, packaging and assembly-line operations for a product.

Corporations and foundations provided funding to continue the program through the early 1990s. While the program was achieving success during that time, it also became apparent that earlier intervention had become critical, and girls should receive enrichment and encouragement in the STEM fields prior to entering high school. In 1992, the National Science Foundation (NSF) had also recognized the need to encourage more females to pursue educational programs and careers in science and engineering and issued a call for proposals. Thus, funding from NSF in 1992 led to another FEMME program, the Introduction to FEMME (IFEMME), for post-fourth and post-fifth grade female students. Continued NSF funding over the next two years allowed further expansion for the creation of the FEMME Continuum (FEMMEC), which became a bridge between IFEMME and FEMME. By the end of the 1990s, under the direction of Suzanne Berliner-Heyman, Nicole Berliner Koppel and Rosa

Cano, a continuum of programs for female students had been implemented that included the establishment of five FEMME groups in a Women in Engineering and Technology-FEMME (WIET-FEMME) initiative. Starting with post-fourth graders and going through to post-eighth graders, a true continuum had been established from the upper elementary level into the secondary level. Approximately 70 percent of FEMME participants have been returning alumni, as the program at each grade level provides new and unique opportunities and experiences for the students each summer.

As part of the academic continuum, a primary thematic unit was created for each group that integrated all STEM subjects and activities, and was aligned with existing New Jersey Content Standards for appropriate grade levels. Over the course of the continuum, students are introduced to a variety of engineering and technological disciplines in a comprehensive manner, while enhancing their science, technology and mathematics skills and increasing their self-efficacy in the STEM academic areas. Within each unit, engineers are introduced as problem-solvers who utilize engineering principles to create and develop devices and objects that meet needs in the modern world.

The FEMME programs: (clockwise from upper left) FEMME8 participants dissect a sheep's heart; FEMME7 students test acids and bases; FEMME5 participants build kites; and FEMME4 students catch samples of ocean lift at Sandy Hook.

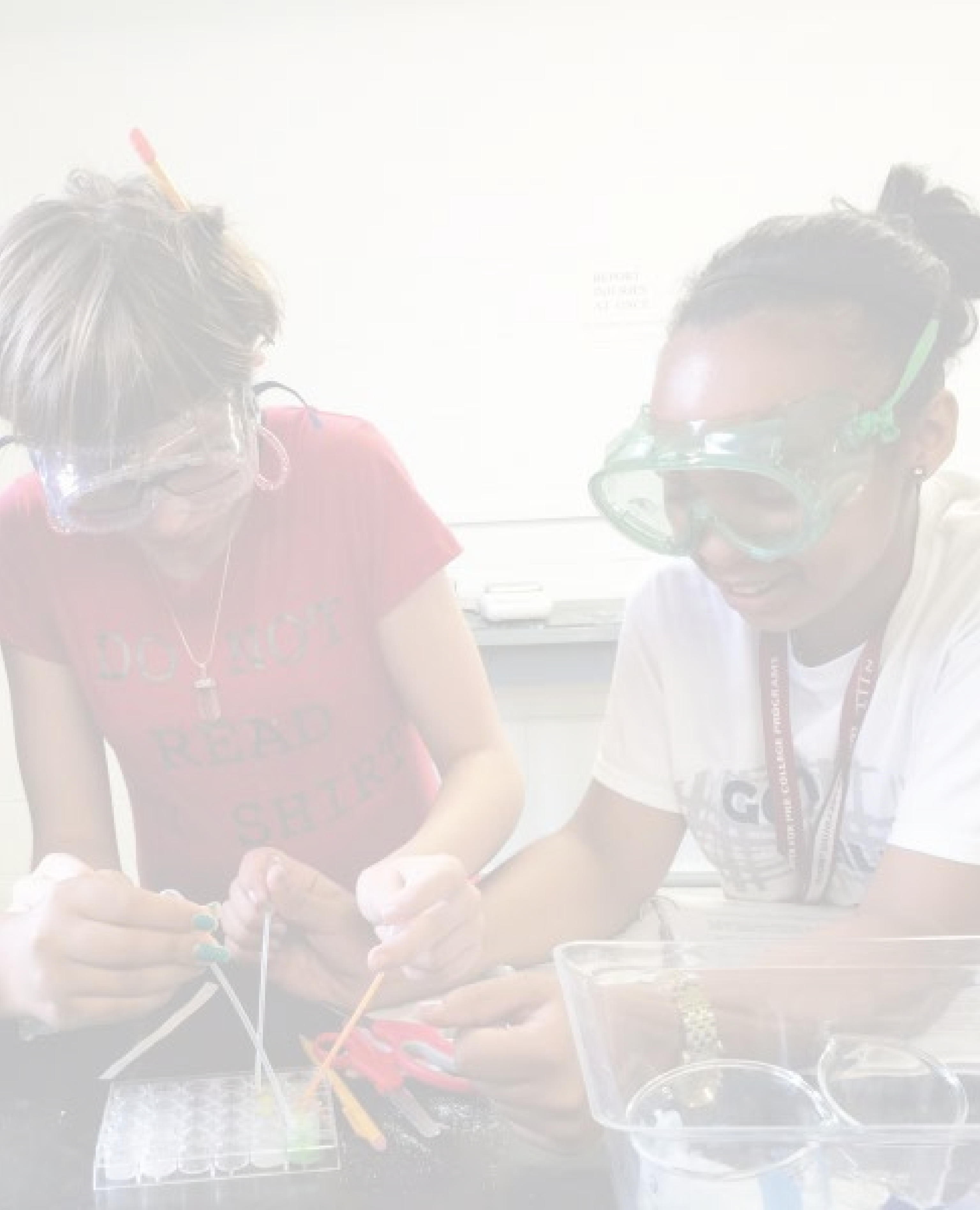
The thematic units are:
– FEMME4 – Environmental Engineering.
– FEMME5 – Aerospace Engineering.
– FEMME6 – Mechanical Engineering.
– FEMME7 – Chemical Engineering.
– FEMME8 – Biomedical Engineering.
– FEMME9 – Electrical and Computer Engineering (later to change the focus to Coding).

For example, in the chemical engineering unit (FEMME7), the seventh-grade girls learned about chemical engineering and chemistry with a focus on how the world looks through the eyes of a chemical engineer. Topics studied included chemical equilibrium, chemical kinetics and separation methods, and how they are related to our everyday lives, with applications to cosmetics and household products. As a final project, students performed laboratory experiments to test claims made by manufacturers about a chemical product. In one instance, students became involved in toothpaste development, as they were able to experience first-hand manufacturing of their own toothpaste. After testing toothpaste ingredients to establish the individual attributes of these ingredients, they were able to formulate their own toothpaste based on the desired qualities.

WIET became fully institutionalized at NJIT and has since become part of the university's mission to recruit, retain and graduate women in STEM fields. But as the NSF funding disappeared and corporate and foundation funding became more difficult to obtain, new methods of funding the programs became necessary. Sources of funding were primarily payment of tuition either by parents or by school districts. Limited corporate and foundation funding was used to provide scholarships for low-income participants when school districts could not pay for the tuition.

A former FEMME participant became a member of the CPCP Industrial Advisory Board. Liza Negron grew up in Newark and graduated from NJIT in 1994 with a B.S. in chemical engineering. She works at ExxonMobil as an intellectual property attorney specializing in patent law. "I can't tell you the importance of having a mentor. Mentors are key," she said. "I am a big proponent of STEM education for kids. I never had the benefit of these types of programs. As a kid growing up in Newark, I didn't see anyone who looked like me doing the things I wanted to do. My message to the kids is that you can do anything if you set your mind to it. Don't let your socioeconomic status preclude you from dreaming big."

As the WIET became institutionalized, CPCP began receiving complaints from parents of male students as to why the center was discriminating against boys. Thus was born a parallel set of coed programs. The Early College Preparatory Programs (ECPP) became an umbrella for the WIET and co-ed programs. By 2013, a set of programs for boys only was implemented.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Chapter 5

STEM (Science, Technology, Engineering, Mathematics) Programs

Through the 1990s and the early 2000s, the acronym SMET (Science, Mathematics, Engineering and Technology) was commonly used to represent the four disciplines. However, throughout that period of time, the use of SMET only considered the subjects as individual entities, each encased in a type of silo. The acronym was changed to STEM and arose in common use shortly after an interagency meeting on science education held at NSF in 2005. Since then, STEM has become a significant aspect of K-12 educational reform in classroom practice and curriculum reform, as well as in workforce development. The significance of STEM education lies in the links that connect the skills and knowledge in each discipline and in the fact that these fields are very connected in the real world.

Many K-12 educators still approach STEM disciplines as if each one (science, technology, engineering and mathematics) exists in isolation from the others. Alternately, they may believe that an engineering experience and/or robotics can be considered a STEM program, even if an engineering problem involves only doing some arithmetic or a scientific concept, which is not explored in the activity. The distinction between technology education and educational technology is also an area of confusion. For those in educational technology, there is the view that the "T" for technology means only the use of technology for educational purposes, such as the use of computers, as opposed to educating students on various technologies, their development and their application.

STEM education is meant to be an interdisciplinary area of study that integrates the four disciplines rather than the achievement of skills and knowledge independently in each subject area. A STEM program should integrate the content and skills of the disciplines and engage students on many levels, as well as provide students with experiences using problem-solving, analytical and communication skills. Thus, STEM programs should be an interdisciplinary and applied approach that is coupled with hands-on, problem-based learning. As a result, a student should possess the ability to apply understanding of how the world works within and across the disciplines of science, technology, engineering and math.

Energy, Environment, Technology

While the STEM acronym started to become popular at the turn of the 21st century, NJIT began the concept of integrating the four subject areas into an interdisciplinary unit in 1975, when NSF granted the university funds for an in-service program: Energy and Environmental Technology for Secondary School Teachers. It was a four-year grant that provided a one-year graduate course for teachers each year. While Dr. Kimmel was principle investigator (PI) for the grant, the NJIT interdisciplinary team consisted of four members of the faculty: Professor Reginald Tomkins (chemical engineering and chemistry), Professor Achille Capecelatro (physics), Professor Manual Perez (mathematics) and Dr. Kimmel. The nature of the subjects of energy and the environment requires that they be studied in an interdisciplinary manner – a study in STEM. The interdisciplinary approach was enhanced by the use of scientists, engineers and an architect as guest lecturers, who contributed a range of expertise in various areas of energy and the environment.

The course was designed to present secondary school teachers with an overview of the complex energy problem and environmental issues associated with energy production and usage, and to provide the background necessary to understand energy conservation methods and alternative resources. Emphasis was placed on subject matter that could be incorporated into their classroom practice and curricula, either by developing specific courses on energy and/or the environment, or by including aspects of energy and environmental issues into the traditional science, math or technology/engineering courses. The latter alternative would have been an early interdisciplinary approach to STEM subjects, and could also have involved an interdisciplinary team-teaching approach.

An important outcome of this course were the comments from some of the participating teachers that, while there was a large amount of energy curriculum materials available for the science classrooms, there was very little available for the mathematics teachers. This issue was reinforced at a Practitioner Conference on Energy Education held at Rockford College in Illinois, in December 1979, at which Dr. Kimmel was an invited participant. The conference objectives were to develop recommendations for public interest groups, industry, and federal and state agencies. A major recommendation of the conference participants, who noted the lack of energy curriculum materials in mathematics, was the infusion of energy topics into all disciplines and educational levels. Accordingly, the center collected and disseminated a collection of energy materials and resources with a description of how they could be integrated into a mathematics curriculum and classroom instruction.

The topics of energy and the environment were not only important as real-world applications, they could also provide the links between the concepts of the different STEM areas and serve to promote the relationships of the subjects through mathematical notation and models, scientific laws, technological objects and engineering design, as well as links to concepts studied in earlier lessons. Thus, these connections could promote STEM integration and student learning as they are addressed through classroom learning experiences and curriculum design. This led the center to continue the focus of its in-service programs in the 1980s on the topic of energy.

A grant from the U.S. Department of Energy in 1982 for a faculty development program allowed the center to provide an energy education professional development program for elementary grade teachers (grades one to six). While such programs for secondary school teachers were available, there were very few such programs being provided for elementary school teachers, due to both a lack of curriculum materials and because most elementary school teachers were apprehensive toward such technologically oriented subjects as energy. The workshops were meant to give teachers the confidence and background knowledge to feel comfortable teaching the subject, and provide them with appropriate instructional approaches and curriculum materials. Public Service Electric & Gas became a partner in this effort, allowing the center to continue the program for several more years while providing additional funding and an engineer, Harry Roman, as a co-presenter for the workshops. Separate workshops were provided for teachers in self-contained classrooms (i.e., the teacher instructs in all subjects), and teachers responsible for two or three subjects (i.e., science, math and in some cases social studies).

The workshops were designed to improve and enhance the knowledge background of the teachers and their ability to teach about energy topics and issues, so that the topic of energy could be incorporated into the curriculums of science, mathematics and, where appropriate, other subjects such as social studies. The basic format of a workshop included:

– Energy overview and basic concepts.
– Utilization of an Energy-Environment Simulator (to be described later).
– Identification of sources of appropriate curriculum materials.
– Selected demonstrations and hands-on classroom activities.

The workshop facilitators were able to explain concepts, such as forms of energy, energy conversion and efficiency, heat transfer, thermal radiation, potential and kinetic energy, the laws of energy, insulation and environmental pollution, at a basic level appropriate for elementary teachers and students. Further, such topics lent themselves to suitable and effective hands-on student activities and teacher demonstrations. All activities and demonstrations required only inexpensive materials readily available either in the home or supermarket. As there were no suitable background materials available for them, a handout titled, "Basics of Energy: An Introduction," was developed by the workshop facilitators and distributed to workshop participants. The handout provided background on the concepts with real-world applications, such as the production of energy by such methods as the burning of fossil fuels, or hydroelectric power

In 1981, the U.S. Department of Energy designated the CPCP at NJIT as a host site for the Citizens' Workshop on Energy and the Environment program, which was facilitated by Dr. Kimmel, Professor Tomkins and Professor James Grow (chemical engineering and chemistry). The program was designed to increase public awareness of the then current world energy problems and point to possible solutions. The focus of this program was the Energy-Environment Simulator, a specially designed analog computer that simulated real-world conditions. Energy resources, energy demands, population and environmental effects were programmed into the electronic device. Thus, the simulator was capable of varying a large number of parameters affecting either the supply of energy or the demand for energy, as well as determining the rate at which the energy from each source was supplied for the various demands. A digital clock, proceeding at the rate of a century a minute, allowed the operator (either a workshop facilitator and/or a member of the audience) to make decisions about the allocation of energy resources in response to changing conditions on a continuous basis. It should be noted that the workshops were also concerned with the total energy picture, including renewable and nonrenewable energy resources. A significant outcome was the observation that the simulator proved to be a most effective way to demonstrate the exponential growth rate of energy consumption vs. the available supply of nonrenewable energy resources.

The program content, and how the simulator was used, depended on the nature and size of the audience and the time allocated. In this context, presentations were made as appropriate:

– During a regular college class.
– During a school class of students in the K-12 sector.
– During energy education, and professional development workshops for K-12 teachers.
– To professional groups of scientists or engineers.
– To civic and other general public groups.
– As a display at conferences or public events and areas.

Audience participation was enhanced by the availability of five remote control boards that could be used by members of the audience (individuals or teams of participants).

Energy education workshops continued, upon request, into the 1990s. In 1983, a grant from NSF allowed the center to provide a professional development program on Energy Education for Secondary School Science and Social Studies Teachers. This was a collaborative effort between CPCP and the NJIT Humanities Department. Professor John O'Connor of the Humanities Department was the co-PI for the program. This program helped to support the importance of the arts, humanities and language skills. In its most concentrated state, STEM is a complete integration of the entire academic curricula.

The interdisciplinary approach to STEM continued. In 1992, a grant from Exxon Chemical-America allowed for a professional development program for elementary and middle school teachers. A three-year grant from NSF in 1994 supported a professional development program each summer for middle school teachers called Hazardous Waste Management.

As a companion to the professional development program for middle school teachers on Hazardous Waste Management, funding from NSF in 1995-1997 led to the implementation of a three-week, commuter program called Young Scholars Project in Environmental Waste Management, for 30 students entering grades eight and nine. Through mentoring by NJIT research faculty members, these high-ability, predominately underrepresented students received instruction in the scientific process and became engaged in research in the engineering science associated with hazardous substance management, so as to motivate them to pursue careers in science and engineering. In addition to the research, learning experiences included classroom and laboratory activities, seminars and field trips.

Pre-Engineering Instructional and Outreach Program (PrE-IOP)

The transition to the implementation of comprehensive teacher-training and curriculum-improvement programs occurred during the period of 2001-2004 with the implementation of the Pre-Engineering Instructional and Outreach Program (PrE-IOP), funded through a three-year High-Tech Workforce Excellence Grant from the New Jersey Commission on Higher Education. PrE-IOP was a joint initiative between CPCP and Newark College of Engineering, with a mission to enlarge the future pool of qualified high-tech workers, including those who were traditionally underrepresented in the STEM fields (e.g., minorities and females). (Also noteworthy, PrE-IOP marked the beginning of a very fruitful collaboration between Dr. Kimmel and Ronald Rockland, engineering technology and biomedical engineering, which continued until Dr. Kimmel's retirement in June 2012.) By the third year of the program, PrE-IOP had an impact on about 60 school districts and 80 schools. This started the center's synthesis of professional development, alignment of classroom practice with state standards, curriculum review, development and modification, and student assessment. The focus of PrE-IOP was on different fields of engineering: biomedical, chemical, civil, electrical and mechanical, and the integration of these engineering disciplines into the STEM courses of the middle school and high school curricula. The design of PrE-IOP was based on the assumption that effective science/pre-engineering secondary school curriculum and teacher training, coupled with better understanding of the STEM professions, would eventually lead to significant increases in enrollment in the STEM disciplines. Accordingly, this comprehensive program consisted of two major components:

– An instructional component that focused on the integration of engineering curricula materials in middle and high school STEM courses.
– An outreach component that included an information campaign about the rewards of STEM professions.

The instructional component, under the auspices of the Education and Training Institute, included the adaptation and/or development of integrated curriculum modules for use in middle and high school classrooms, and the provision of professional development opportunities for the teachers. The modules were designed to integrate pre-engineering skills and knowledge of design and problem-solving into science, technology, engineering and mathematics courses, aligned with state curriculum content standards. Under the auspices of the Education and Training Institute, academic-year workshops and summer institutes were provided to familiarize the teachers with the curriculum and the associated instructional approaches, with appropriate follow-up and support during the school year. Subject areas included biomedical engineering, chemical engineering, electricity and magnetism, machines, integrating engineering concepts into the science curriculum (also offered as an online short course during the year) and integrating engineering into high school mathematics. This infusion of engineering concepts and design into existing STEM courses was coupled with awareness components that included discussions and activities illustrating who and what engineers are and what they do. Practicing engineers and engineering students were included as role models.

As an example, the discipline of chemical engineering was directly related to the study of chemical principles usually studied in a high school chemistry course. Utilizing these principles, teachers learned chemical engineering concepts, such as material and energy balances, batch and flow processes, and plant design. The difference between the practicing chemist at the workbench and the practicing chemical engineer in an industrial site was emphasized. Practicing chemical engineers and undergraduate chemical engineering students were part of the team of workshop facilitators. For instance, when the role of females was featured, focusing on different engineering fields, a female engineering student collaborated with a member of the chemical engineering faculty to introduce the process of engineering and the relevance of chemical engineering to everyday life. The student discussed the nature of and required preparation for her studies in chemical engineering, why she chose this field of study, and the barriers she had to overcome to pursue her career goals.

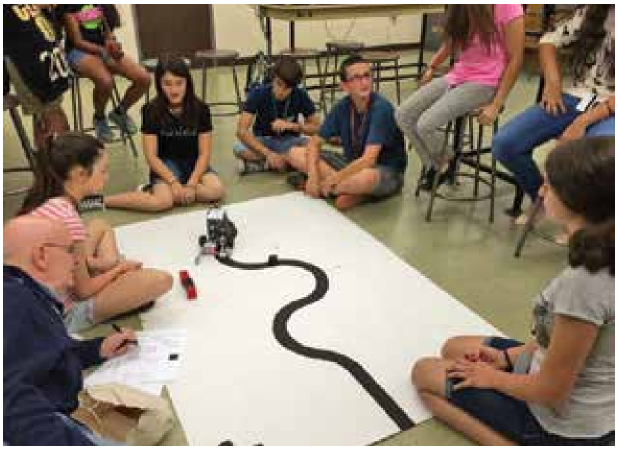
The outreach component involved the implementation of an Engineering the Future Outreach program and the formation of alliances with three groups of stakeholders – educators, counselors and parents – to promote STEM careers. Collaborations with STEM professionals and professional associations were utilized to help strengthen stakeholders' ability to encourage students to investigate STEM careers. The stakeholders were able to observe and hear from practicing professionals about the challenging, highly rewarding job opportunities and career paths, and the social, economic and environmental impacts of their work. As part of the program, workshops were provided for the counselors. In addition to print brochures, the outreach program used multimedia presentations, including videos, interactive CD-ROMS and a series of teleconferences with the theme "Building an Engineer."

The first teleconference was titled "Building an Engineer: How to Help Our Students." Through this teleconference, middle school and high school educators were introduced to experts in the field of engineering and engineering education. A group of panelists discussed various engineering issues, including the nature of different engineering fields, high school preparation, post-secondary engineering programs, entering the industry, parent and community involvement, and gender issues. The panel included a representative from a professional organization, an industrial person, a college professor of engineering, a secondary school teacher, a high school counselor, a gender-issues expert and a parent who had a child pursuing a college engineering degree. The teleconference was hosted at various universities and secondary schools across the State of New Jersey.

Medibotics Program

An outgrowth of PrE-IOP was the Medibotics project (Medicine and Robotics), a three-year project funded by NSF under their ITEST (Information Technology Experiences for Students and Teachers) program. The Medibotics project was developed to use robotics to integrate information technology (IT) applications into the teaching and learning of scientific and mathematical concepts, and to link them to physics, mathematics, technology, engineering and problem-solving. Medibotics was meant to represent the merging of the specialties of medicine, robotics and information technology, as it focused on the development of projects that were medical in origin and that utilized IT, engineering and technology to incorporate grade-appropriate prototypes of robotic surgeries into middle and high school STEM curricula. Because of its multidisciplinary nature, the study of robotics in the classroom has become a valuable tool for the practical, hands-on application of concepts across various engineering, mathematics and science topics. In addition, the Medibotics program linked several topics within the field of IT, including the logical sequence of actions needed to program a robot to perform a given task. The actual programming of the robots emphasized the basic programming skills inherent in IT, and the programming of remote, autonomous devices. Components of the Medibotics program included development of surgeries, professional development, standards-based lesson planning, capstone experience and classroom observations.

The grade-appropriate prototypes of robotic surgeries were first developed for biomedical engineering students at NJIT. The curriculum was developed through a collaboration of university faculty and secondary school teachers as a way for students to be able to apply classroom lessons in robotics to real-life problems rather than just robotics for the sake of robotics. Thus, students in their classrooms were able to learn to design and build robots to perform simulated robotic surgeries, which had elements of actual medical procedures. Medibotics used the LEGO® Mindstorms for Schools with Robolab software kits to solve biomedical engineering problems. The Robolab software used an icon-based, diagram building environment to write programs. This icon-based environment enabled students at lower grades to perform simple to complex programming tasks. These types of kits provided an overview of how multiple fields of science, such as biology and medicine, mathematics and engineering, from electrical engineering (sensors and motors) to mechanical engineering and physics (gears, axles and hinges), could be combined with IT (the programming languages that help support the input and output from sensors to motors).



Students demonstrate their LEGO® Mindstorms Challenge robotics project at a Medibotics showcase.

Teachers were provided with intensive professional development to train them in how to integrate the pre-engineering curriculum and the robotics kits into their mathematics and science instruction. The professional development included information and hands-on experiences in the Medibotics program to enhance their STEM instruction. The curriculum was developed as a way for students to apply classroom lessons to real-life problems. Teachers also received instruction in how to develop standards-based lesson plans so that the curricula would be aligned with content standards in science and mathematics. The professional development program included an initial two-week summer workshop and a one-week workshop the following summer. Academic-year follow-up included one-day workshops and in-class support by university faculty, staff and graduate students to work with and mentor the teachers during the implementation process in the classroom and in program assessment, in order to assure that the teachers were able to implement the skills and knowledge acquired during the summer activities. In addition, an electronic, peer-learning community was established for communications among teachers and university personnel and for online professional development activities. During the initial two-week summer workshop, teachers were introduced to the curriculum and shown how to perform four different robotic surgeries for implementation in their classrooms. Elements of the two-week summer workshop for the teachers included:

- Introduction to robotic technology.
- Introduction to appropriate programming concepts.
- Discussion of design process and engineering design.
- Discussion of scientific principles utilized in construction and operation of the robot.
- Introduction to surgery and robotic surgery, while providing additional sources of material and websites.
- Description and demonstrations of surgery projects.
- Facilitation of teacher interaction and discussion so that they were able to collaborate and develop materials.

The peer-learning community was developed to provide an environment that would motivate teachers to learn continuously in the settings where they teach, and apply skills and knowledge of improved curriculum practices, as well as offer opportunities for collaboration, sharing and exchange of ideas. The online community allowed teachers from different school districts, and different schools within the same district, to discuss the robotic surgeries taught within the program. Teachers were able to draw on each other's experiences and support each other as they introduced the surgeries into their own classes. The project staff was also able to use the system to post general discussion questions and to obtain teacher feedback that was used to continuously improve the program. Through this learning community:

- Copies of all workshop notes were provided for easy reference.
- Threaded discussion forums were available for posting of questions by teachers, replies to questions, and information on the workshop topics and the surgeries covered in the summer and fall workshops.
- Wikis were available for collaborative creation of curriculum guides and other teaching materials, and for creating lists of useful resources for the modules.

The selected surgeries involving the robotic systems had elements of actual medical procedures. Students were able to utilize the internet to investigate the various real-world surgical applications, as well as discover the new and exciting application of robotic surgery. Each robotic surgery was developed to model an actual surgery that entailed a different set of tasks and sequence of actions, and required the development of different procedures and programs. The robotic surgeries were presented as problems to be solved. The physiological systems involved were modeled using common craft products and other inexpensive materials that were easy to obtain. Each of the demonstrated surgeries included physical forces and design principles. By utilizing various sensors for each surgery, different scientific principles were demonstrated. In addition, students were able to understand basic programming concepts and were able to demonstrate complex programming in which the robot has to perform actions based on the control of input and output devices incorporated into its design. The robotic surgeries for the professional development program were selected to:

– Demonstrate various surgical procedures and physiological areas.
– Utilize various sensors and relate the scientific principles to these sensors.
– Demonstrate design principles.
– Enable students to understand basic programming concepts.

The robotic surgeries provided teachers with the opportunity to move the study of scientific concepts from the textbook and engage students in hands-on learning of such biology topics as anatomy and physiology, and chemistry topics such as acids and bases, chemical processes and properties of materials. The construction and operation of the robot itself demonstrated applied physical concepts, including motion of objects, levers, gears, forces, rotational torque, movement of the robotic arm (mechanics), principles of electricity and basic circuitry. While principles of applied physics could apply to any of the robotic surgeries, incorporating the Medibotics curricula into the life sciences, chemistry and physics depended on the specific surgery and the choice of sensor. Understanding energy, including light, heat, sound, electricity and magnetism, was necessary for the use of sensors, such as the light sensor and the sound sensor, and required knowledge of properties of light and optics, transfer of energy, and waves. Math topics that were applicable to the robotic surgeries included:

– Measurement.

Jason Baynes

says he was fortunate to have had the opportunity to be part of a pre-college program that exposed him to science and math in many more ways than his school did. In summer 1989, before he entered ninth grade, his mother enrolled him in a program at NJIT called the Junior High School Urban Engineering Program (JHSUEP). Administered by the Center for Pre-College Programs, JHSUEP focused on engineering, as well as how science and mathematics can be applied to real life.

"The experience was awesome!" Baynes remembered. "Not only did the program make learning science fun, it also allowed me to help my classmates in science and math class when I returned to school in September."

His passion for learning how to apply science in the real world stemmed from JHSUEP and ultimately led him to become an orthopaedic surgeon. As such, he is able to combine his love for helping people with the newest technologies that are brought to market daily by bioengineers — both of which allow him and his team to get people back to using their arms and legs like they did before sustaining their injury.

"I must wholeheartedly thank Dr. Kimmel and his staff for pioneering the Center for Pre-College Programs at NJIT," said Baynes. "I feel that without my early exposure to learning science in a fun way, I may not have become the physician that I am today."

– Geometry – angles, distance, polygons.
– Percent error and accuracy.
– Percents, comparison statements.
– Solving algebraic equations – variables.

As an example of a surgery, teachers were asked to design, construct and program the robot to perform a heart bypass surgery. In this surgery, Twizzlers represented blood vessels – the red were healthy and the black were unhealthy with cholesterol. The robot was to be designed to perform the corresponding surgery that would move the robot to the blood vessel, test it for cholesterol and leave it alone if it was healthy (red). If the blood vessel was unhealthy (black), the robot had to remove it and replace it with a healthy one. During the summer training program, each team of teachers found many different designs and creative approaches. Through this surgery, teachers were able to:

– Demonstrate physical forces: balanced forces, torques and momentum.
– Demonstrate design principles.
– Demonstrate a complicated sensor (the light sensor is hard to use, but can accurately differentiate between colors).
– Demonstrate complex programming (this robot has to perform actions based on what its sensors see).

Teachers were able to utilize the Medibotics curriculum in many ways. For example, one teacher augmented a life-sciences lesson with examples of how robots could be used to enhance the study of functioning parts of the skeletal system. Comparisons were made between the joints of humans and robots and their comparative flexibility. Students experienced both types of structure and how each performed based on its assets and limitations. Conversation with this teacher indicated that he planned to coordinate a robotic experience with each of the content areas in the school curriculum. Another teacher modified the ninth-grade general science curriculum, so that robotics had been integrated into each of the areas of earth, physical and life sciences. For example, in earth science, students programmed robots to "explore the surface of Mars." Robotic surgery was introduced as an application in the life sciences.

A workbook of support materials including background lessons, sample solutions, diagrams, building instructions and relevant STEM lessons for each of the surgeries was developed. The first six chapters provided an introduction to the concept of the Medibotics program, biomedical engineering and robotic surgery, and covered the basic concepts for the construction and programming of the robot. Also included were lessons in science- and mathematics-reinforced topics covered in the various surgeries, and details for ten surgeries. These surgeries were included in the workbook, seven of which were developed by participating teachers as a result of the professional development program. Each of the ten robotic surgeries had the following sections to help guide teachers in utilizing the surgeries within their classes:

– Background information on the surgery.
– Introduction to the surgery.
– The robotic "physiology" for the surgery.
– An example solution for the surgery.
– Building instructions for the base robot.
– Hardware overview for sample solution.
– Sensor overview.
– Software for the sample surgery.
– Sample programming solution.

A capstone experience was integrated into the program to help determine whether the desired skills and knowledge were acquired by the teachers and the resulting impact realized in their classroom practices. A traditional capstone course is an opportunity for students to demonstrate that they have achieved the goals for learning established by their educational institution and major department. The capstone experience in the Medibotics project was designed to be a shared, culminating learning experience for the teachers through a self-directed, integrated, learning opportunity. The capstone required the teachers to integrate principles, theories and methods learned throughout the program. Teachers needed to creatively analyze, synthesize and evaluate learned knowledge in a project having a professional focus and then communicate the results of the project effectively to their peers. It was an opportunity for teachers to demonstrate that they were able to apply the acquired skills and knowledge from the training program and serve as an instrument for the assessment of teacher outcomes that resulted from the professional development program.

Teachers had been shown how to perform four different robotic surgeries. To assess how well they understood the concepts of the surgeries, teachers in teams of two were assigned the task of creating a new surgery, using the robotic system, and then teaching it to their peers. Creating a new surgery was modeled after a capstone course (or senior project) in the engineering and engineering technology disciplines. This could have been a different surgery (or computer-assisted procedure) that involved the same physiological system as in the four previous surgeries, or it could have been a computer-assisted procedure that involved a new physiological system. Surgeries were presented to their peers, who provided feedback on each surgery, including suggestions for implementation in their own classrooms. Previously specified professional development learning objectives for teachers were applied to the teacher-developed surgeries to assess their achievement of expected learning outcomes as a result of the training program.

Successful classroom implementation by the teachers was also seen by the students' ability to apply their newly acquired skills and knowledge in fun and meaningful ways. Competitions can provide such opportunity. To ensure that the Medibotics program was a learning experience for the students, a competition called the Medibotics Showcase was held on the campus of NJIT for selected students from each participating teacher's class based specifically on the Medibotics curriculum. Student teams competed against one another to see which team could design and build a robot to remove a kidney stone. The robot needed to find and move colored blocks outside of a region (the kidney), simulating the removal of a kidney stone. Students were awarded points based on accuracy and time to complete the task. There were constraints put on the construction of the robot, but there was enough flexibility to allow for creative design. Student teams were allowed two trials for the competition, and time was allowed for the student teams to adjust their robot and their strategy, based on the results of the first trial. Besides the competition part, students were required to keep an engineering logbook during the entire development and testing of the robot. In addition, students were required to create posters of their design and the surgical background. All three elements were graded.

Virtual Medibotics

The Medibotics program was a collaboration of CPCP and Newark College of Engineering led by the team of Dr. Kimmel, Professor Ronald Rockland (Departments of Engineering Technology and Biomedical Engineering), Levelle Burr-Alexander (CPCP) and Professor John Carpinelli (Department of Electrical and Computing Engineering). With a grant from the ExxonMobil Foundation, the NJIT team created and implemented a web-based professional development system, titled Virtual Medibotics™, that enabled STEM teachers outside the commuting region to access the Medibotics teaching resources online and implement the Medibotics program in their classroom. The system included predefined web-based instruction with computer-mediated communication that supported the interactive participation and collaboration among teachers.

This web-based approach to distance learning allowed both asynchronous and synchronous delivery options to accommodate the wide range of activities necessary for completion, including readings, teacher contributions to discussion, and assignments for teachers. Discussion forums allowed teachers to share content, ideas, instructional strategies and alternative perspectives. The web-based instructional modules provided learning objects (e.g., videos), reading assignments, links to related websites, examples from the workbook and self-assessment measures. Assessments were developed for each of the learning objects (videos), as well as for the learning outcome(s) related to that learning object. This allowed the team to follow the progress of each teacher. The material was uploaded to a course management system, which gave the teachers the ability to post questions. The videos were a result of a complete workbook from the Medibotics program.

There were two primary online resources for this program: a general website made available to the general public and an online resource that was used by participating teachers. The material used for training consisted of over 30 videos that focused on learning objects within the program. Two cohorts of teachers participated in the program; program materials for the second cohort were modified based on the assessment and feedback from the first-cohort teachers. The program consisted of a series of modules:

- The first module presented the basic elements necessary to construct a robot, programming procedures, and background information on the Medibotics program and engineering design process and the LEGO® Mindstorms NXT system.
- The second module showed the development and implementation of a mock coronary bypass surgery.
- The third module examined the elements of a dental crown surgery that reinforced the basics of programming and introduced the teachers to more advanced topics.
- The fourth module had the teachers modifying a surgery, without any additional assistance, to test their own knowledge as a lead-in to the capstone project.
- The capstone project was the final module, designed to be a shared, culminating learning experience for the teachers, where the teachers had to develop their own surgery. This allowed for teachers to learn through a self-directed, integrated process, and project staff was able to assess how well the teachers had understood the materials and were able to implement the Medibotics curriculum in his/her classroom. The website allowed the teachers to upload their capstone projects, which also provided additional surgeries for future participants.

The capstone project required teachers to select a surgical procedure and implement it. Teachers who were able to extend their work in this project to create their own robotic surgeries clearly demonstrated that they had achieved a high level of competency in the program. For the surgeries, the teachers were required to use either two sensors and three motors, or three sensors and two motors, and had incorporated much of what they had learned throughout the program. Teachers were also required to submit a report on their capstone surgery, which included:

- An introduction to the surgery.
- Physiology background related to the surgery.
- What we call the robotic physiology for this surgery, which is the robotic representation of the physiology.
- The algorithms developed for the surgery.
- A list of key STEM topics related to the surgery.
- The programming to implement the surgery.
- Bibliography.
- A video showing their robot as it successfully completed the required procedure.

A series of three milestones was established over the course of this professional development system. The first milestone was the completion of the first surgery, demonstrated by teachers uploading a video of this surgery to the website. The second milestone was the completion of both a second surgery and a variation of a second surgery, where the variation was more open ended than the original two surgeries. Again, a video showing completion of the assignments was uploaded. The third milestone was the completion of a capstone surgery.

A major difference in the online version as compared to the original Medibotics program should be noted. It is the period of time for professional development. In the original Medibotics program, the training was performed over a fixed period of time with school-year and summer workshops, which worked well for local schools. Completion time for the online version varied among the teachers due to existing distractions and priorities.

A total of 60 teachers in two cohorts signed up for the program. The first cohort of 20 teachers represented schools across the State of New Jersey, most of whom could not have participated in the original Medibotics program. The second cohort of 40 teachers was from several states in the

Mid-Atlantic and Northeast regions, including Maryland, Delaware, Pennsylvania, Connecticut, Massachusetts and Vermont.

Research Experiences for Teachers (RET)

The Research Experiences for Teachers (RET) program was a collaboration of the Engineering Research Center for Structured Organic Particulate Systems and CPCP. The goal of the program was to educate high school teachers in the opportunities and challenges involved with manufacturing of pharmaceutical products, and thus help educate future generations of students and create a strong pipeline of talented students interested in pursuing careers in the STEM disciplines. The program provided high school science and engineering technology teachers with a professional development program that enhanced their research skills and their knowledge of science and engineering concepts, and enabled them to incorporate real-world applications (e.g., pharmaceutical engineering) into their high school STEM curricula. A process was introduced that allowed the teachers to develop and implement curriculum modules based on their research, and that incorporated best educational practices. The educational professional development component for the teachers was under the direction of Dr. Kimmel and Dr. Burr-Alexander, with Linda Hirsch (program evaluator for CPCP) providing the background on treatment of experimental data and statistical analyses for the teachers.

RET teachers were expected to adapt/develop lesson plans based on their research experiences. As a result of their participation in the research experience, teachers were able to:

- Enrich their knowledge base as STEM education professionals by participating as active members of a research team at NJIT in the area of pharmaceutical engineering.
- Gain a better understanding of how scientists and engineers engage in research and how the term "inquiry" is integral to the research process.
- Translate their research into classroom content by synthesizing their research experience and integrating the acquired content knowledge and skills into a learning module for the high school students, which supplements and enriches the school/district curriculum.
- Develop lesson plans that were aligned with content standards.

Teams of teachers worked on research projects side by side with their faculty advisors and post-doctoral/graduate student mentors. Through the RET project, teachers learned the content, process, culture and ethics of modern scientific research through total immersion in the process of scientific inquiry and engineering problem-solving. The RET program provided the guidance that helped the teachers maximize their research experience in order to have practical, laboratory exposure working with their mentors as well as gain insight into how and why scientific research is done. Teachers also were able to document their experience by communicating their work in a presentation at the end of their summer experience and relaying it to their students in their classrooms.

In addition to the laboratory research component, the six-week summer program consisted of numerous workshops on research-related topics, such as laboratory safety, information literacy, treatment of experimental data and statistical analysis, as well as educational topics. By the end of the summer program, teachers had completed their research projects and drafted lesson plans. Educational activities for teachers included:

- Development of professional growth plans and project expectations.
- Enhancement of their knowledge of experimental design and statistical analysis.
- Translation of their research into classroom practice.
- Development of interdisciplinary lesson modules based on their research, aligned with state and national content standards, and incorporating best educational practices that brought their research to a level appropriate for students in high school science (biology, chemistry and physics) and engineering technology courses.

The nature of the instructional module was determined

(Clockwise from upper left) High school teachers Charles Muchira, Marie Aloia, Paul Orbe and Mina Armani conduct research in an NJIT laboratory as part of the Research Experiences for Teachers program.

by the examination of the high school curriculum and selection of topics that were closely related to the pharmaceutical industry as well as the teacher's research. Subjects taught by the various participants included biology, chemistry, physics and engineering technology. Teachers were able to select projects that were relevant to the subjects they were teaching. For example, an engineering technology teacher selected a research topic related to manufacturing. The problem was related to the fact that powdery materials have certain properties that include size, density and flow among others. The goal of the research was to improve the manufacturing process by altering the size and composition of the components in the drugs. Methods included breaking large powders into smaller ones with pressure and adding small excipients to improve flow, a manufacturing concern. A chemistry teacher chose a project that involved polymer films. There were several other related small projects like viscosity studies of the polymer solutions. The procedure involved precise measurement of the mass of solute and solvent and preparation of the exact concentration of the solution, followed by measurement of the viscosity of the solutions. Comparisons of the viscosity of different solutions were made using graph and statistical analyses.

The summer program included a presentation by a member of the faculty who had extensive industrial experience. The presentation provided an overview of the process of developing solid dosage forms and their manufacture in the pharmaceutical industry. It included not only the introduction to key concepts, but also a description of the workings of the pharmaceutical industry and some of the drivers in this industry.

During the following school year, teachers implemented their lessons in their own classrooms and collected samples of work products that documented student achievement of specified learning outcomes. They then presented their work to their teacher colleagues and researchers at a one-day symposium that December. This included a description of the lesson module and the outcomes achieved by their students.

The success of the NJIT RET program was reflected in the number of teachers who continued to seek a place in the following RET programs. One such teacher was Marie Aloia, who was a participant in the first RET program, and since 2007 has been the only teacher to have been invited back each year to participate in the program. Her participation in the RET program led her administration in Bayonne to ask Aloia to create and implement an engineering program for the district. And she did. Aloia had earned a B.S. degree in chemical engineering from NJIT, and worked in industry for several years before entering the teaching profession as a chemistry teacher. She was well qualified to implement and teach engineering at the high school level, and implemented a successful homegrown three-year pre-engineering program over a period of six years that had benefited greatly from her RET experience.

In the RET program, the teacher had to be both a researcher working with someone who was doing this project as his or her doctoral or post-doctoral research, and a teacher looking to bring some exciting new topic back to a science or engineering class. The RET program had an influence on Aloia in the development of the engineering curriculum, because she saw that the research had to be treated as a project from start to finish. The specific research topic may not be, and sometimes could not be, directly related to the lessons for the classroom, but the experience always brought the development of new skills and knowledge. For example, from her RET experience she concluded that the final project for the students in the engineering courses would not necessarily be based on a project they did all year, but on applying the key concepts and principles of topics they learned in a practical presentation on an engineering manufacturing topic of their choice.

The course that began the program, and became its mainstay, was a fundamentals course, Introduction to Engineering. It was primarily designed as either a stand-alone course or as preparation for a post-secondary engineering program. A review of basic physical science concepts, such as work, energy and Newton's Laws, was integral to the course. These concepts served as a kind of toolkit for solving engineering problems. Each year the content was modified and refined, as needed. The course included the engineering design method, systems engineering, creative problem-solving, reverse engineering, team-building exercises and an overview of the engineering disciplines and applications. Each topic included introductory notes, a glossary of terms and vocabulary quiz, problem sets, at least one project and documentation. Since the course did not utilize a textbook, students were expected to build a reference binder for notes, handouts and assignments, and maintain an engineering notebook for their small projects.

In the second-year engineering course, students were able to select their own projects and build a personal portfolio. Lightly structured, the engineering course included a FIRST Tech Challenge robotics team, membership in a chapter of the Technology Students Association (TSA), and access to local programs and competitions. Some students entered the course with a portfolio in hand. The teacher served as a resource and mentor, as the students presented weekly plans and progress for a grade. Students who successfully completed the second-year engineering course and were not graduating seniors were able to take a next-level class in engineering. In this class students were given the freedom to build their own portfolio of projects, of which at least one had to be suitable for a competition. Many of the students had already been prepared for this by being recruited by members of the current engineering class for projects such as the TSA TEAMS competition and extracurricular robotics. The more motivated students had created their plans for this engineering course as they finished the Introduction to Engineering course.

While the Introduction to Engineering course could be taken by 10th or 11th graders, the course Engineering Technology was developed primarily for ninth-grade students. It focused on engineering design, project management and hands-on technical skills, and allowed students to advance to the Introduction to Engineering course with a richer preparation.

In addition, a course on research for science and engineering students evolved as a curricular and/or extracurricular activity during the development and implementation of the engineering classes. Its purpose was to provide students with the necessary tools to develop research projects that could be entered in a competition and/or science fair.

The best time for research was in the summer, because most of the lab work and research was done before the beginning of the school year and the project would be ready to be formatted for competitions during the school year. Sometimes students continued their research, too. The whole purpose of the research class, both the curricular and extracurricular versions, was to develop a research project that could be entered in as many venues as possible. In addition, the senior engineering class was a portfolio class, where students were required to do at least one competitive project. Some did several projects. The students were required to take the Introduction to Engineering class, earn a grade of "B" or better and demonstrate that they could develop and manage a project in order to enroll in the research course. While most students started in September in this class, the better students were already discussing ideas with Aloia for their senior projects in the spring of their year in the Introduction to Engineering class. Some students obtained summer internships to do

(From left) Students in the Early College Preparatory Program (ECPP), Introduction to Chemical Industry for Minorities in Engineering, conduct a lab; a fourth grader in ECPP's Environmental Science and Engineering examines a lava lamp he made; and a middle schooler in ECPP's Explore Careers in Technology and Engineering tests his balloon-powered car.

research, while others just worked on their own.

A unique feature of the NJIT RET program was the participation of selected students with their teacher in the summer research. It can be considered unique since there does not appear to be any reports available in the literature of an RET program having this feature. It was in 2008, the second year of the RET program, that the first two students came to work with Aloia on her RET project. The female students selected to be part of the research team were from the research class described previously. Aloia's project that year was still being defined, so with the extra hands (i.e., the students), she was given a more complicated project. The project was very successful, more than the post-doctoral mentor was expecting. In fact, the project was passed on to a doctoral student after Aloia and her students were finished, and presented at an NSF meeting in the spring. Aloia still has the poster from the presentation hanging in her classroom with her name and that of the doctoral student as presenters and the two students named as research participants. In addition, the same girls presented their science-fair poster at this NSF event. At the end of the summer, the students were asked about their experience in the laboratory. One was very gregarious and thanked everyone. The other was shy and so soft spoken that the graduate student working with Aloia and her students asked her if the student had a voice. The student said very simply, but boldly, "Thank you for letting me work in your laboratory. You have taught me that I want to study engineering in college." Since that year, Aloia has participated in each program in the following years and brought students with her each year. Many students did more research after the summer to add to what they had learned. Some came back to the NJIT library to access the journal collections. In most cases, their summer work helped them decide on what to study in college.

Of note are the many different post-secondary institutions that the students have attended and what they have studied or are studying. Some were special success stories, like one student who came to NJIT in his first year of college as part of the Research Experiences for Undergraduates program. He majored in theoretical chemistry on an American Chemical Society scholarship before he entered the M.D./Ph.D. program at Tufts. While most of the students enrolled in engineering, science or pre-medical programs of study, some students stepped into other fields. One student became a science writer and interned at a local paper during his time at Rutgers University. Another student went into social work for criminal justice, but minored in forensics to keep her foot in a STEM topic. And another student studied applied math and operations research; he had helped on the project that did predictive modeling.

Early College Preparatory Programs (ECPP)

Starting with the implementation of the Urban Engineering Programs in the 1970s, all student enrichment programs utilized an interdisciplinary approach to the study of the STEM subjects. Thus, all Early College Preparatory Programs (ECPP) covered the STEM topics in an interdisciplinary fashion using engineering as the integrating factor. The WIE-FEMME programs were described earlier. The non-WIE-FEMME programs have included:

- Environmental Science and Engineering Program (ESEP) – Fourth Grade.
- Aeronautical Engineering Program (AEP) – Fifth Grade.
- Pre-Engineering Program (PrEP) – Sixth Grade.
- Explore Careers in Technology and Engineering (ExCITE) – Seventh Grade.
- Chemical Engineering Program (CHEM-ENG) – Seventh Grade.
- Intermediate Robotics (iRobotics) – Eighth and Ninth Grade.
- Biomedical Engineering Program (BIO-MED) – Eighth Grade.
- Introduction to Chemical Industry for Minorities in Engineering Program (IChIME) – Seventh and Eighth Grades.
- Fundamentals of Physical Sciences - Chemistry/ Physics (FPS-C and FPS-P).

The ExxonMobil Bernard Harris Summer Science Camp (EMBHSSC) was an all-inclusive residential program founded by NASA astronaut and physician Bernard Harris Jr. Dr. Harris was the first African-American astronaut to walk in space, and he was a veteran of two space shuttle missions and a former NASA researcher. Under the direction of Suzanne Berliner-Heyman and Dr. Hirsch, the two-week camp uses an interdisciplinary approach to introduce STEM to approximately 50 students entering sixth, seventh and eighth grades from underserved and

Physician and former astronaut Bernard Harris (left, top row, third from left; upper and lower right, second from left) visits with students at the ExxonMobil Bernard Harris Summer Science Camp hosted at NJIT.

underrepresented populations. NJIT has hosted the camp since 2007. As of 2017, it is the only university in the New York metro region to host this camp and one of only 10 universities in the nation. The camp's approach selects a different theme each summer while utilizing activities, experiments, projects and field experiences that support that theme and enriching participants' mathematics, science, technology and communication skills.

An example of a theme that was utilized one summer was "Engineering Your Place in Space," in which the campers were challenged to use high-level thinking skills to design an area in a space station to live and work. Accordingly, they attended classes that included problem-solving, research, critical thinking and communication skills incorporated into biology, chemistry, physics, environmental sciences, earth sciences, engineering, technology and design concepts, and went on field excursions to places like the Buehler Challenge & Science Center, where they were able to simulate a mission in space.

The columnist David Brooks once wrote in The New York Times about the wide educational gap between the rich and poor in America. Brooks wrote that the major part of the problem is that students from poorer families are not "academically prepared, psychologically prepared and culturally prepared for college…"[1]

NJIT's pre-college programs have a strong track record in addressing this challenge. Alumni of this program have not only received undergraduate degrees from prestigious universities throughout the U.S., but have gone on to receive master's and doctoral degrees in more than 30 scientific disciplines, as well as medical and law degrees. The center will continue its efforts to transform the lives of hundreds of New Jersey students and prepare them to become the skilled professionals needed for the high-tech economy of the 21st century, and to increase the number of members of underrepresented groups in the scientific and engineering workforce.

Competitions

Successful classroom implementation of STEM has been reinforced by providing students the opportunity to apply their newly acquired skills and knowledge in fun and meaningful ways. Science fairs and competitions are supposed to allow students to combine their problem-solving skills with acquired STEM skills and knowledge, while utilizing readily available, inexpensive resources to solve real-world problems. These activities are meant to provide students with the opportunity to connect the STEM subjects with the use of real data to solve real problems.

Unfortunately, science fairs have tended to become extremely competitive experiences, where cute or flashy displays have become more important than the design of the project or the actual scientific investigation. While outside help and advice could be beneficial to the students, more often it has become counterproductive due to excessive involvement by parents and other adults, the amount of money spent and excessive use of technology, thus creating an environment where many students are trying to mimic activities found in books rather than conduct scientific investigations to solve real problems. Students tend to focus on the mechanics of their studies rather than demonstrate an understanding of the phenomena that was the subject of their study.

It was these issues that were discussed when Ed Brakowski, an engineer at Panasonic, and colleagues of the Panasonic Industrial Company met with the center in 1991 to discuss Panasonic's support of an event that would provide students with the opportunity to apply their scientific and mathematics skills and knowledge to solve engineering problems. And it would not be a science fair. Also, NJIT students would be recruited to design the challenge and develop the rules for it. Thus, the partnership of NJIT and the Panasonic Industrial Company established the yearly Creative Design Competition for teams of high school students.

[1]Brooks, David, "The Education Gap." The New York Times, September 25, 2005. Access at: http://query.nytimes.com/gst/fullpage.html?res=9B03E1DA1430F936A1575AC0A9639C8B63

See also: Tavernise, Sabrina, "Education Gap Grows Between Rich and Poor, Studies Say". The New York Times, February. 9, 2012. Access at: https://www.nytimes.com/2015/09/23/business/economy/education-gap-between-rich-and-poor-is-growing-wider.html?_r=0

The competition was meant to provide an opportunity for students to apply their critical-thinking skills with knowledge and skills acquired in their classrooms, and utilize inexpensive and readily available resources to solve real-world problems. Each year an identified problem or theme was posed that provided opportunities for students to develop their own solutions to the problem. A maximum limit was placed on the cost of materials and students were encouraged to use recyclable or throw-away materials. A list of specifications and selected electronic components was provided to each team.

In addition to a demonstration of their working solution to the problem, students were required to:

– Keep an engineer's logbook.
– Submit a written report.
– Make an oral presentation of their solution to a panel of judges.

Teams of judges were made up of university and corporate professionals. Students' solutions were judged on technical aspects, cost-effectiveness, and written and oral descriptions of their product.

The first competition in 1991 was based on the diminishing availability of petroleum for transportation and the impact of burning fossil fuels on the environment. Alternative methods were needed for powering the different modes of transportation, especially automobiles. The challenge for the students was to design and build a wheel-less (i.e., no axles) vehicle using Panaflo fans and batteries (supplied by Panasonic) as the energy source for the vehicle. The students were allowed to use the fans and batteries in any combination of one or two fans with one or two batteries, so that they would be able to balance the power factor with the weight factor.

As another example, the following competition in 1992 had the theme of "Technology and Environment," which challenged the students to design and construct a working model of a simulated solid-waste resource-recovery plant that could separate a mixture of simulated recyclable waste materials into its pure component products. The recyclable waste consisted of one cubic foot of a dry mixture of wooden toothpicks, paper clips, Styrofoam packing pellets, fish-tank gravel and a single, standard-sized plastic thread spool. Students were given specifications and limitations as to size, cost, methods and materials for their model plant. The students' model plants were judged on their performance, the cost-effectiveness of their design, and students' written and oral presentations on the design approach and principles on which the model plants were based, to demonstrate how the students were able to apply their knowledge of mathematics, physics, engineering and design to construct the best-performing and cost-effective design.

An interesting occurrence was how the Panasonic engineers became stimulated by the challenge. A team of the company's engineers spent 300 man-hours to design and build a resource-recovery plant for the competition. Then they were at work the night before the competition to make sure that their device was superior to any that the students built for the competition.

In less than 10 years after the first Panasonic competition, other competitions, mostly utilizing robotics to accomplish tasks, started to gain popularity as an effective way to apply classroom learning to solve real problems. These competitions included FIRST Robotics, LEGO® League and JETS at the national level, and BEST and Botball Robotics at the regional level, as well as competitions at the local level, such as the New Jersey Science Olympiad (the state version of the National Science Olympiad) and the New Jersey Chemistry Olympics. The Science Olympiad covered all the STEM fields, with several of them involving robotics, while the Chemistry Olympics focused primarily on science. NJIT has participated in most of these competitions, serving as host and providing judges and an event supervisor and/or supporting teams of students. While many students were able to use their classroom learning experiences in terms of the science and engineering that should go into the building of a device, it was found that some students showed more interest in the building of a device and less interest in the science and engineering necessary to operate or optimize the operation of the device.

After a brief hiatus, in the early 2000s Panasonic resumed its competition with two significant changes:

– The name was changed to the Panasonic Creative Design Challenge (PCDC).
– Each new challenge involved a mobile device, usually a robot, carrying out assigned tasks.

In addition, each summer Panasonic hired a team of NJIT engineering undergraduates as interns to develop, design and test a new challenge for the next school year. Occasionally, this team has included a recent high school graduate who was also a PCDC competitor.

While new themes were developed each year, each challenge now required students to create a mobile device (usually a robot) that could withstand the complexity of an arduous course. Each challenge still required teams to apply a wide range of mechanical and electrical engineering and mathematical skills to be successful. Teams were judged on the quality of their written report, oral presentation and engineering logbook entries, as well as on the performance of their device. Winning teams each year have been awarded special category prizes as well as scholarships to be used exclusively for college expenses. Teams also have received free Panasonic merchandise.

For a given challenge, teams still had to build a device utilizing inexpensive and readily available materials that could include items such as popsicle sticks, duct tape, hot glue, wire spools, string, wooden dowels, soda cans, bottle caps and paper. To motorize the devices, the students might use small direct current (dc) motors and LEGO® gears and axles that Panasonic supplied. The amounts of motors and gears/axles were generally limited in order to increase the difficulty of completing the challenge. The popularity of the competition grew to the point that a preliminary competition was held several weeks ahead of the final competition as an elimination round. This preliminary challenge usually involved some subset of the final competition. At the final competition, each team was allowed three trials to acquire the most points in the fastest time. Between trials, each team was given about 90 minutes to make adjustments and/or repairs to their device before the next trial.

At the New Jersey Science Olympiad, (left) students build their Rube Goldberg device during the Mission Possible event, and (right) NJIT's Laurent Simon and two NJIT student volunteers judge a device.

Examples of challenges included:

– 2008: “Murky Waters” – Teams were required to design and construct a device that could pick up LEGO® people, descend into the “murky waters,” traverse different terrains and surface areas, and climb various ramps.

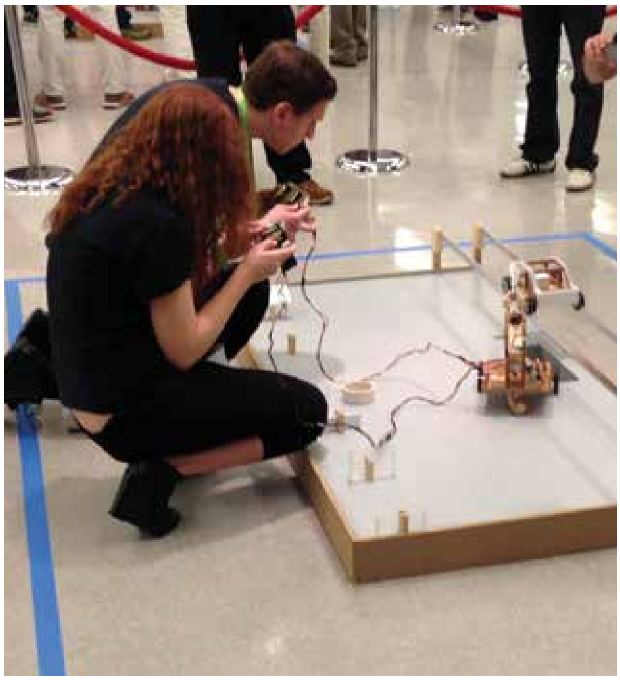
– 2009: “Beach Sweeps” – Teams were required to design and construct a device that could clean up an ocean shore by:

  – Picking up and sorting plastics and metals.
  – Powering and lighting a solar panel.
  – Planting sea grass into dunes.
  – Moving an artificial coral reef into the ocean.

The 2010 challenge is worth noting here as it brought back a different version of the 1992 theme of recycling. The 2010 challenge was titled “Pana-Plant” and involved creating a device that could sort various materials into respective recycling bins. Also interesting is that this challenge was the only one since 2000 that, instead of requiring the construction of a mobile device, required teams to design and construct a device that could complete the challenge without a need to move. The teams were required to design and construct a device to sort different items: five nails, five marbles, five AA batteries, five wooden cubes and five bottle caps into their own recycling bins. The difficulty of the task was the need to create a device with a very high level of specificity and efficiency to successfully sort everything quickly. The successful teams eventually realized that a multistage device would be required to efficiently sort each type of item individually. Thus, this represented a much more complex task than the previous recycling task of 1992, and probably more complex than most other challenges, and required a higher level of mathematics and engineering and design knowledge and skills.

The Science Olympiad is another competition of much interest. It is a team competition in which students compete in “events” pertaining to various scientific disciplines, including earth science, biology, chemistry, physics and engineering. There are multiple levels of competition: regional, state and national. Top scoring teams at the regional competitions advance to the state level, and then to the national level. For any of the competitions, there are two divisions of events: Division B for middle school teams and Division C for high school teams. Specific events may be held at a given competition for either Division B and/or Division C. The events for the two divisions vary in the degree of knowledge and skills required of the students on the participating teams.

Events fall under five main categories: life, personal and social science; earth and space science; physical science and chemistry; technology and engineering; inquiry and nature of science. Although most of the events emphasize engineering, or one of the science disciplines, some events are interdisciplinary in nature, focusing on science and engineering and also requiring applications of math concepts and sometimes communication skills. For example, Write It Do It is an event requiring communications skills. For this event, one team member is given an object or device. That member then must write a set of instructions on how to build it. The other team



Students conduct their first performance run at the 2017 Panasonic Creative Design Challenge.

member is given the instructions written by their teammate and a set of unassembled materials to attempt to recreate the object as accurately as possible. Such application of writing comprehension and skills is reinforced through connections with the content. In other events, students are asked to describe how they addressed the task or problem. Other events apply concepts from social science to science and engineering.

From the first National Science Olympiad tournament in 1985, until 2010, New Jersey held only a state competition, with winning teams advancing to the national competition. The number of participating teams reached a point, however, where three regional competitions were necessary to select those teams qualified for the state competition. NJIT became the host site for the northern regional competition.

Dr. Kimmel served as the event supervisor and one of the judges for the Mission Possible event at the state competition for several years, until the regional competitions were introduced. At that time, he became event supervisor and one of the judges for this event at the northern regional competition at NJIT instead of at the state level. In this event, students are expected to design, build, test and document a Rube Goldberg-like device that completes a required final task through an optional series of simple machines. A Rube Goldberg device is a contraption or invention that performs a series of tasks to accomplish a simple, single task using indirect and complicated means. Construction of the device requires the utilization of concepts of science and engineering, and the application of several mathematical skills.

Mission Possible is a very exciting event for both the students and the judges. It is also a very competitive event for the teacher-coaches of the teams – so much so, that at one state competition, the coaches became argumentative and abusive with the judges. It got so bad that Dr. Kimmel told the competition supervisors that unless there was a "guard" at the event to keep control of the coaches, he would no longer supervise the event. The following years, a person was assigned to control the coaches and they were kept at a distance during the event in the state competition. For the regional competition, only the student teams have been allowed into the room for the event.

One interesting aspect of this competition is a common problem many of the participating teams have experienced over the years. Each year several teams find that, while their device worked properly at their school, it didn't work as designed at the competition. Dr. Kimmel had to remind these teams that the devices are fragile and can be impacted by the ride from the school to the competition site. Thus, before the competition, they need to take the device for a "drive," and then check it out back at the school.

Chapter 6

Dual-Enrollment Programs

Allowing students to enroll in college courses while completing their high school studies was an initiative of NJIT that dates back to the early 1980s. These early-entry programs, as they were known at that time, provided high school students with the opportunity to earn transferable college credits, shown on a college transcript, while experiencing the workload and expectations of taking college courses – thereby leading to improved retention and persistence of these students in college.

The first NJIT early-entry program came in the 1970s as the High School Scholars Program. A faculty partnership of the Departments of Physics and Mathematics developed and implemented an integrated calculus/physics course, which was provided for Newark high school students on the NJIT campus and team-taught by NJIT faculty. Students who successfully completed the course earned credit for the first semester of college calculus and first semester of college physics. The early-entry program expanded in 1979 when the principal and the science supervisor at Newark's Science High School came to Dr. Kimmel, as associate chair for chemistry in the Department of Chemical Engineering and Chemistry, to discuss the possibility of Science High School students enrolling in the freshman chemistry course. After consultation with and approval by the university administration, it was decided to schedule a full section of the freshman chemistry course in midafternoon, which included two hours of lecture, one recitation and a two-hour laboratory over the course of the week. This would permit the enrollment of qualified Science High School seniors at NJIT for the scheduled classes before they went home. The significant difference between the chemistry course and the integrated calculus/physics course is that the latter consisted only of high school students, whereas the two semesters of freshman chemistry included actual NJIT students as well as the high school students. Thus, high school students were actually enrolled in a college course, sitting in the same classroom as the NJIT students, and receiving the same instruction with the same expectations. It was a valuable experience for the high school students, in addition to their receiving college credits for successfully completing the two-semester course.

Several years later, NJIT offered the first college course for high school students via distance learning. During the period of the late 1980s through the early 1990s, ACCESS-NJIT provided complete telecourses, equivalent to on-campus offerings, to high school students at Bayonne High School in New Jersey. The instructors of telecourses stood in a television studio at NJIT, taught through a live satellite hookup routed through a television studio at Union High School, and brought advanced instruction to the school. Thus, NJIT faculty provided live interactive (two-way audio, one-way video) telecourses to students in their classrooms in the presence of the high school teachers. Students and teachers were able to ask questions through a parallel telephone hookup, taking place at the same time as the broadcast. The high school teachers then provided recitation/problem-solving sessions/laboratories, as appropriate, for the students in their classrooms. NJIT textbooks, curriculums and tests were utilized so that students successfully completing the course(s) were able to earn NJIT course credit as well as high school course credit. NJIT courses in physics, chemistry and calculus were provided through ACCESS-NJIT. Physics I, taught by Professor Ronald Gutreau, was the first course offered, followed shortly by Calculus I taught by Professor Rose Dios. In 1990, Dr. Kimmel started teaching Chemistry I and Chemistry II through ACCESS-NJIT.

It was an interesting and stimulating experience teaching through a different medium to a live classroom a distance away. Actually, Bayonne High School was not too far away, and Dr. Kimmel found that one could actually see NJIT from the rooftop of Bayonne High School. Why then was it necessary for the TV signal to go through the studio at Union High School to get to Bayonne? The reason was the heavy traffic of electronic signals from the airport that passed between Bayonne and Newark. For Dr. Kimmel, this indirect transmission of the course was not noticeable until the time that the regular technician at Union High School was absent one day and a student was manning the studio. As the course video to Bayonne came on the air, the voice of Bruce Springsteen was heard at Bayonne instead of Dr. Kimmel's. Apparently, the student erred in making the correct connections. That class was postponed until another day. The unfortunate and regrettable thing was that while each class was recorded, that one class with the singer's voice was not recorded.

The Pre-College Academy at NJIT was designed for academically talented high school students who wanted to begin their college careers while still in high school. It was initiated in 1991 as a Summer Academy program in computer science and had grown to include the sciences (chemistry and physics), pre-calculus and calculus, humanities, information technology, freshman engineering design, management and economics. Participants earned college credits that could be applied toward an undergraduate degree at NJIT and at most other colleges and universities. The Summer Academy included regular college students, so that the high school students were able to experience an urban university environment where they could meet and learn from other talented high school students as well as from college students and faculty. Academy courses offered on Saturdays during the school year were developed through partnerships with local school districts where their students were registered in regularly scheduled classes that often included undergraduate students – an environment where all students would be expected to perform to the standards expected in a college-level course. The students encountered an environment that they never had before, one where they began to understand what would be required of them as college students. Academy students also had access to all college facilities including the library. All of this gave them a campus experience that should have eased their transition from a high school environment to a university campus environment. During the summer, students were able to stay in on-campus housing if they wished, rather than commute. This program continues today.

There have been many success stories from the Pre-College Academy and the center. But perhaps none has been more compelling than the story of a Newark student by the name of Stefan. When he first entered the Summer Academy, he had already been in the Project Grad Program of the center. Stefan was an 11th grader at Malcolm X Shabazz High School, who had exhibited a good aptitude for mathematics, but had yet to prove his ability. At the urging of the director of Project Grad (Armand Berliner, professor of mathematics), Stefan was enrolled in the Summer Academy course Math 102, Pre-Calculus. Stefan discovered many things that summer, not the least of which was his love of learning and teaching others mathematics. When the Summer Academy spoke with administrators at Shabazz after that summer, all of them told of Stefan's metamorphosis – how he had become a tutor in math to not only younger middle school students, but also students older than himself. While he received an "A" that summer, more importantly he returned to Shabazz as a mentor to his peers and extolled the virtues of taking higher mathematics courses and going to college. That fall he continued his studies by enrolling in Calculus, Math 111 and earned a "B." He also took the SAT for the first time and earned a total score of 1180. In the spring he took Physics 111 and 111A, earned an "A" and applied and was enrolled at NJIT on a full scholarship. In his first semester, he was able to take what were normally considered second semester freshman courses, and decided to pursue a degree in mathematics and receive certification as a teacher of mathematics. The Pre-College Academy had awakened a gifted learner.

More than 25 years after our first college course offering for high school students, and 13 years after the implementation of the Pre-College Academy at NJIT, the dual-enrollment concept (also known as concurrent enrollment) was introduced in New Jersey in 2004 by the New Jersey Department of Education as an initiative for post-secondary institutions across the state to provide opportunities for high school juniors and seniors to enroll in a college course at the high school site. The students could earn both high school credit that counted toward their high school degree and college credit for the course as shown on a college transcript. These courses also counted for high school credits for graduation.

Since the announcement of the initiative by the New Jersey Department of Education, the dual/concurrent enrollment program of NJIT has provided college-credit courses for high school students at their high school campus through its Options Program. The program has provided qualified high school students from partnered schools with the opportunity to take college credit courses at their school during the regular academic year. These courses have been taught by high school teachers certified by NJIT as adjunct faculty members in the related NJIT departments. The number and level of college-credit courses offered have depended on the academic preparation of the students, the availability of qualified faculty at the high school, and access to specialized equipment and facilities (for example, computers and laboratories). The course syllabus, textbook, requirements and credit value for each course have been the same as on the NJIT campus. Students who have successfully completed the course work have received college credits that appear on an NJIT transcript. These credits are generally accepted by two- and four-year colleges in the U.S.

Courses available for participating secondary schools have included: architecture, chemistry, computer science, economics, engineering design, English, information technology, management, mathematics and physics. Freshman- and sophomore-level courses from other departments have been made available upon request of the high school, and if suitable instructional arrangements can be made. When a qualified instructor has not been available at the high school, alternative methods of course delivery have been arranged. For example, a high school

Liza Negron Sutowski

is an engineer, a lawyer and a businesswoman, and she uses her knowledge of each field to excel at her job. She works as an intellectual property attorney for ExxonMobil Corporation specializing in patent law and advising colleagues and clients, including ExxonMobil researchers, on environmental and antitrust issues. It is the perfect job for her, since it combines her love for science, math and the law. And her engineering background helps her understand emerging technologies.

Her interest in STEM was cemented after her sophomore year in high school when she took a physics class offered by the Center for Pre-College Programs (CPCP). Negron Sutowski, who grew up in Newark, later enrolled at NJIT as a first-generation college student and graduated in 1994 with a B.S. in chemical engineering. She went on to earn a master's degree in environmental engineering from the University of New Haven, a law degree from Pace University School of Law and an MBA from Rutgers University.

As an alumnus of both CPCP and NJIT, Negron Sutowski has returned to participate in many activities. She delivered the keynote address at the STEM Summit for High School Girls, co-sponsored by CPCP and the Garden State Woman Education Foundation. She also was a guest speaker at the ExxonMobil Bernard Harris Summer Science Camp, a two-week residential program hosted at NJIT that introduces STEM to students from underserved and underrepresented populations.

"I am a big proponent of STEM education for kids," said Negron Sutowski. "I never had the benefit of these types of programs.

"When I talk to young people, I always tell them you never know where your path will lead you," she added. "A lot of your direction and success in life will depend upon finding the right mentors."

in northern New Jersey wanted to offer a college-level economics course for the students, but it did not have a qualified instructor for the course. NJIT's Martin Tuchman School of Management was able to arrange for an adjunct who was willing to travel to the high school to teach the course. It was taught in a single three-hour block in the late afternoon.

For the 2011-2012 academic year, the Options Program was offered at seven different school sites for 135 students, with 14 courses from the Departments of Chemistry, Engineering Technology, Humanities, Mathematics and Physics, the School of Management and Freshman Engineering Design. The success of the Options Program is evident in a typical comment from teachers of the dual-enrollment courses at their high school:

"Thank you for all your encouragement and assistance in giving our students this opportunity. I know the students who have been successful have appreciated the opportunity, and students who did not meet the expectations felt that the experience of being challenged at that level has helped prepare them for college."

The Academy Program served as a vehicle for the establishment in 2011 of a mathematics partnership with Newark's Central High School (CHS). In many urban areas, such as Newark, it has been shown that many students were earning "Ds" and "Fs" in their algebra and/or geometry courses and still being allowed to enroll in more advanced math courses at the high school. For example, students earning an "F" in Algebra I were then enrolled in Algebra II; students with a "D" and/or "F" grade in algebra were enrolled in the high school pre-calculus course. Historically, students from underserved and underrepresented backgrounds have struggled when taking mathematics assessments for admission to institutions of higher education, resulting in denial of admission – or if they are admitted, dropping out of college due to their frustration and lack of support.

The program was initiated after the principal, Ras Baraka (now mayor of Newark), and counselors expressed their interest in enrolling the CHS students in an NJIT course on the NJIT campus during the last periods of the high school day. Ensuing discussions led to the collaborative development and implementation of a program in which CHS students would be enrolled in the NJIT pre-calculus course (4 credits) on the NJIT campus during the last periods of the day. The mathematics partnership with CHS was designed to help the high school students overcome hurdles to success by providing mathematics instruction to CHS students selected for the NJIT pre-calculus course. An agreement of understanding was developed that described the expectations for the high school students and the staff at CHS, and for NJIT. The students attended the class on the university's campus and were taught by an NJIT mathematics instructor while earning college credit.

The pre-calculus course operated according to the university's semester schedule with adjustments made according to the schedule of the Newark School District. CHS provided transportation from the school to the NJIT campus each day for the course, which occurred during the last two class periods of the high school day. On Mondays through Thursdays, the students received math instruction from Jimmy Hayes, an NJIT mathematics instructor, as well as tutoring by volunteer NJIT students. On Fridays, the counselors of the TRIO program provided counseling services that dealt with issues such as cognition and low self-efficacy, and also worked with the students to improve other critical skills such as note taking, study habits, time management and communication, all of which were reinforced in the classroom setting. Student selection was based upon grades on report cards and recommendations of teachers, counselors and TRIO staff. A preliminary meeting was held for students and parents in the spring before the start of the next school year to describe the program, and the expectations that were held by the high school administration and the NJIT staff. This was meant to emphasize the need for motivated students who would attend the class whenever scheduled and participate fully in all aspects of the course. The success of the program was seen in the first two years where nine of 13 students completed the course with a grade of "C" or better in the first year and 13 of 14 students completed the course with a grade of "C" or better in the second year.

Mohamad Camara (left) and Tim Ellis are 2017 graduates of NJIT and the first graduates of the Math 099 class (now Math 110), a special partnership and pre-college initiative between NJIT and Central High School.

The first offering of the course in September 2010 proved to be a tremendous challenge to Hayes, both in terms of student weaknesses in basic math skills and the intangibles that could mean success or failure for the students. First, Hayes found indications of student issues that needed to be addressed immediately in order to have a productive learning environment. These included a lack of confidence, classroom etiquette, personal discipline and genuine respect that students had for teachers, themselves and their peers. Therefore, the first couple of weeks were focused on correcting and/or adjusting these intangible factors for a good classroom environment. Then it was necessary to identify the level of mathematical skills of the students. Diagnostic assessment tools were used by Hayes to determine the level of the basic math and algebra skills of the students. The results of the assessments indicated a need to strengthen the students' basic math skills before tackling algebra, skills that students are expected to possess as they enter middle school. The next couple of weeks were spent on strengthening the identified areas of weakness. It was interesting to note that as the basic math skills of the students improved, there was also an apparent increase in their confidence level.

In retrospect, this was a very challenging first semester for Hayes, but also a rewarding one. He was able to "witness the self-realizations and discoveries that the students experienced about the world of mathematics." He further reported, "I have seen a lot of growth in the students mathematically and personally. They are excited about math for the first time. Their confidence has greatly improved."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Chapter 7

Flexibility and Adaptability to React and Meet Changing Needs of Students, Educators and Schools

From the time of its inception, the Center for Pre-College Programs has maintained its flexibility and adaptability to meet changing conditions and changing needs of the students, educators and schools that it serves. This mission can involve gifted and talented students or students with special needs, or a single small charter school or a large school district that is adopting instructional strategies, appropriate curricula and assessments so that their students can achieve the skills and knowledge specified by state and national standards.

Alignment With Standards

The first New Jersey Core Curriculum Content Standards for science were based upon the 1993 publication of the Benchmarks for Science Literacy (The American Association for the Advancement of Science, AAAS), followed in 1994 by a comprehensive draft of the National Science Education Standards (NSES) by the National Research Council, and the Scope, Sequence and Coordination Project of the National Science Teachers Association. The simultaneously emerging national standards presented a reliable model that was acknowledged by several nationwide surveys for the excellence of the New Jersey science standards. The science standards, along with those for other subjects and a newly formulated set of Cross Content Workplace Readiness Standards, were adopted by the State Board of Education as New Jersey's Core Curriculum Content Standards (CCCS) in May of 1996.

Concurrent with the adoption of the standards themselves was a mandate that they be regularly reviewed, and revised if necessary, every five years. Note the terms "reviewed and revised IF NECESSARY." As noted above, this first set of standards adopted in 1996 was viewed nationally by many as excellent standards. The first review of the standards occurred about 2002, and the second one in 2009. For the standards in mathematics, only minor changes were made in the two reviews. Not so for the science standards. The revised science standards for 2002 involved a decrease from 12 standards to 10 standards, as follows:

- For life science, the two standards in 1996 were combined to form one standard in 2002.
- The standard (5.1) that focused on systems in the study of science was deleted. At the time, the interdisciplinary approach to the study of science may have still been a novelty and thus considered unnecessary. It is not known if teachers would still use a systems approach in their classroom practice. On the positive side, however, the standard on environmental science remained. As STEM is now considered an interdisciplinary approach to the study of the subjects, the Next Generation Science Standards (NGSS) have an emphasis on "cross-cutting concepts," one of which is systems.

The next review in 2009 became what many felt was a disaster for the science standards. These new ones consisted of four standards – one on science practices and three on science content: life science, physical science (chemistry and physics were combined into one standard) and earth systems. Totally eliminated were the standards on mathematical applications and technology applications, as was the standard on environmental science, among several others. At open hearings, educators at all levels across the state expressed their concerns with the downgrade of the science standards. When the New Jersey Department of Education representative was asked why math and technology applications were eliminated from the science standards, the response was "Teachers will find them in the mathematics standards and the technology standards." This response was a total contradiction to the development of STEM as an interdisciplinary approach to the disciplines. With regard to the technology standard, the representative's response to the university educators was, "You guys are only interested in recruiting students." He emphasized that the science standards were to be limited to four, and if we were to add a standard, then we would have to choose which standard to eliminate. Justification for the limit to four standards for science was never given. One final note: After these standards were adopted, the New Jersey Department of Education representative responded to the concern regarding the elimination of the standard on environmental science. He provided a workshop at the New Jersey Science Teachers Convention for earth science teachers to demonstrate how environmental science is a natural part of the study of earth science. Of course, he neglected the fact that environmental science is a cross-disciplinary subject of all science content areas, not just earth science.

After the adoption of the initial CCCS in 1996, initial efforts focused on workshops for all K-8 Newark teachers on the implementation of the CCCS-Science. Since then, workshops focusing on the implementation of the standards and their alignment with curriculum for math and science have been provided for school districts across the state, from Closter in northeast New Jersey and Vernon in northwest New Jersey to Willingboro and Delaware Valley Regional High Schools in southern New Jersey and districts in Hudson, Essex, Union, Middlesex and Morris counties across the middle of the state. The professional development programs covered the CCCS through its several revisions, and then the Common Core State Standards (CCSS) and the NGSS after their adoptions.

The early workshops focused on a description of the CCSS and the differences between the standards and their indicators, and offered examples of how participants could implement them in their curriculum and classrooms. As the discussions began with regard to the revisions of the first set of standards, the center's training staff came to the realization that much more needed to be done in training teachers to implement and align the standards with their classroom practices and curriculum. It became apparent that while it was necessary to introduce the standards and the language of the standards, with examples to the teachers, it was not enough.

It was recognized that professional development was integral to effective and appropriate alignment of curriculum and instruction with the standards. However, examination of the center's preliminary efforts indicated that the exposure it provided to the teachers was insufficient for effective implementation of the standards in the classroom. Simply aligning standards with curriculum topics was not sufficient. In one three-year study, it was observed that most teachers were unable to select standards that were appropriate for their lessons and/or indicators for their grade levels. In many cases, too many standards/indicators were chosen for the lesson. It became apparent that a different approach to professional development was needed to have the expected impact of the standards on student learning.

The conclusion from the studies was that teachers needed an explicit process for planning lessons and units that were aligned with standards that would lead students to achieve skills and knowledge specified by the standards. Lesson plans aligned with standards required a different way of planning that included: an alignment of student work expectations and classroom assessments with the standards; measurable learning objectives and expected outcomes of the lesson plans; and the establishment of criteria that could demonstrate student achievement of skills and knowledge specified by the particular standard or indicator. This process for aligning lesson plans would be designed to allow teachers to systematically assess learning outcomes that were aligned with any content standards. In collaboration with Dr. O'Shea, a process was developed that would lead to improvement of teacher classroom practice(s) and increased student learning by alignment with the skills and knowledge specified by content standards. This was to be a process that aligned curricula, instructional practices and assessment of student mastery with the performance indicators described in content standards, and be independent of any future changes or revisions in the standards. The process provided for the creation, implementation and assessment of lesson plans aligned with standards. Professional development programs were then developed to train teachers how to utilize the established process. The process included:

- Identification of measurable student-focused learning objectives.
- Specification of the expected progress indicator from the corresponding content standards statement for each learning objective.
- Development/adaptation of a learning experience (activity) that provided the student with the opportunity to acquire the skill and/or knowledge specified by the learning objective.
- Description of the expected student learning outcome/performance that provided the evidence that the student had acquired the skill and/or knowledge.

The process for the planning of lessons had indeed allowed teachers to systematically assess student learning outcomes aligned with content standards. However, it was recognized that there was also a critical need to gauge the quality of the lesson plans as to how well the learning outcomes were being achieved, by focusing on the criteria that identified and measured the parameters of a lesson plan aligned with the standards. Hence, a rubric was developed at CPCP that evaluated the quality of teachers' lesson plans for the STEM subjects, based on the process for creating the lesson plans.

The development of the Leaders of Learners in STEM formalized the approach of CPCP to provide services to schools and school districts. This approach was not a single program and not a program in itself. It was meant to serve two purposes:

- To provide a description of the center's philosophy for development and implementation of curriculum and the alignment of classroom practice with the standards.
- To provide a description of available guidance and support that had been provided and could be provided to schools and school districts in the areas of teaching practice, curriculum development and implementation, alignment with standards and assessment of student learning to demonstrate student achievement of skills and knowledge specified by content standards for identified grade levels.

The approach was meant to focus on the three distinct, but interrelated, components of teaching and learning:

- INSTRUCTION: How should we teach?
- CURRICULUM: What should we teach?
- ASSESSMENT: How should we measure student learning?

All interrelated activities would be described in lesson plans designed to align the three components into a coherent process. By defining EXPECTATIONS of student learning, CURRICULUM and INSTRUCTION are meant to provide for students to have opportunities to learn, and ASSESSMENT is meant to provide for MEASUREMENT of the extent of student learning. The specification of expectations would allow for the alignment of classroom instruction with state and national content standards.

Grants from the New Jersey Department of Education and private foundations funded more intense professional development programs. A Goals 2000 grant funded programs in Union City and Harrison focused on the implementation of the CCCS in science, and its alignment with the curriculum in those districts' elementary and middle schools.

An intensive professional development program was undertaken in the Harrison School District. A three-year grant from the New Jersey Department of Education was awarded to Harrison in 2006 to provide professional development and technical assistance to seventh- to ninth-grade mathematics teachers in the Harrison Middle School. The project involved an innovative approach to improve the teaching and learning of middle school mathematics, increase the achievement of all students in mathematics, including those with special needs, and evaluate the teachers' classroom practices with recommendations for systemic improvement. The program included:

- Summer institutes for teachers to improve and enhance their skills in standards-based lesson planning, and upgrade their knowledge of

mathematical concepts and effective practice of differentiated instruction.
- Regularly scheduled sessions during the school year.
- In-class support that provided further guidance for teachers in effective instructional strategies, linked with appropriate mathematics content.

Year one was to focus on the seventh-grade teachers, year two was to expand the service to include eighth-grade teachers, and year three was to extend the program to ninth-grade teachers, while continuing to serve the teachers in the earlier grades. In addition to providing the services in year one to the seventh-grade teachers, the program was also meant to model the services to be provided to the teachers in the other grades. In year one, school year professional development was provided on a weekly basis to the group, as were discussions with individual teachers to meet their personal needs. An intensive summer program was also provided electronically. Classroom visitations were part of the program. While the alignment of the curriculum to the standards was a focus, priority was also given to those areas identified as most critical by the teachers. These included:

- Content weaknesses by teachers.
- Preparation and implementation of standards-based lesson plans.
- Alignment of effective instructional practices with the district curriculum.
- Logical textbook sequencing aligned with curriculum and course content.

Year two continued the work with the seventh-grade teachers while extending the project to eighth-grade teachers; however, partway through the school year, the Harrison School District administration terminated the project due to what they perceived as the New Jersey Department of Education's imposition of roadblocks in the successful operation of the project. This was unfortunate, as CPCP had seen significant progress in both the classroom practices of the teachers and student achievement.

Corporate foundation funding from the Wells Fargo Foundation supported professional development in the CCSS-Mathematics for middle school teachers in Newark and New Brunswick. Unfortunately, at the time of receipt of the grant, the director of mathematics for the Newark School District declined participation by the district, determining that the Newark teachers would not require the professional development. As a result, the middle school teachers in the Belleville School District were able to benefit from the program instead.

In addition to workshops for teachers during the school year at their school sites, and a summer institute for both districts at NJIT, the program provided technical assistance to and reflective dialogue with the teachers, as it focused on quantitative literacy in the critical areas that are the foundations for algebra: the number system and expressions and equations.

Urban Collaborations

Since 1970, NJIT has developed a long history of collaborations and partnerships with local urban school districts with a special focus on Newark. Located in the Central Ward of the City of Newark, the initial pre-college programs, focusing on the Newark School District and its students, began with the Urban Engineering Program in 1970.

This was followed soon after by the High School Scholars Program, which provided Newark high school students with the opportunity to earn college credit in calculus and physics. Very shortly thereafter, a request from the principal and science supervisor at Newark Science High School led to the opportunity for Science High students to enroll in the NJIT freshman chemistry course. The extra benefit of this activity was that the high school students sat in the same class as NJIT freshman, so that they could experience a college environment while gaining an understanding of what the expectations would be when they entered college. These programs began a long history of collaboration with Newark to provide opportunities for Newark students to prepare for and succeed in college. In 2011, at the request of the principal and counselors, a mathematics partnership with Newark's Central High School (CHS) was formed to enroll CHS students in an NJIT course on the NJIT campus during the last periods of the high school day. These college-level programs have been described previously in the section on Dual Enrollment.

The Experimental Mathematics, Science & Communications Program (EMP) was initiated in 1989 for post-seventh-grade Newark students. Funded by a local foundation, EMP was a summer program that provided enrichment in math, science and engineering topics. The program integrated math, science, engineering and language activities to sharpen students' problem-solving and communication skills, using hands-on experiences to make learning enjoyable and to motivate the students to pursue STEM disciplines in high school and college. The curriculum included mapping and surveying, numerical cryptography, journal and creative writing, and field trips. Basic concepts in algebra, trigonometry, geometry and statistics were developed, and students applied the concepts to topics in engineering and scientific significance, such as aerodynamics and structures.

Rose Dios, a professor of mathematics at NJIT, was the director of the EMP program and is a true success story of pre-college programs at NJIT. Dios had not intended to go to college. She had planned, instead, to work in a low-level job that would enable her to devote her time and energy to caring for her infant son. But then she participated in the Urban Engineering Program. The academic enrichment and guidance that she received that summer changed her direction and encouraged her to pursue a college degree and professional career. The pre-college experience changed her outlook and life completely. While dealing with personal and financial hardship, Dios went on to earn bachelor's degrees in nuclear engineering and mathematics, a master's degree in mathematics and a faculty position as assistant professor at NJIT. Dios became director of EMP with the goal of impacting students in the way that the Urban Engineering Program impacted her life. Her intent was "to give something back" by helping those urban students succeed as she had.

The Federal TRIO programs and Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP) provide outreach and student services for individuals from disadvantaged backgrounds, with an emphasis on college access. The Federal TRIO programs for Newark high school students have focused on building and enhancing mathematics and communication skills, along with offering personal and career counseling, tutoring, college orientation and enrichment programs in the sciences and computer science. The TRIO programs have included the Upward Bound Program, Talent Search, and Upward Bound Mathematics and Regional

Summer 2010 Talent Search students visit Dorney Park in Pennsylvania to enjoy the amusement rides and learn physics.

Science Center at NJIT, as well as programs for undergraduate students.

The Upward Bound Program was an intensive residential summer and thirty-week academic-year program designed to provide fundamental support to participants in preparation for post-secondary education. The program offered opportunities for participants to succeed in pre-college as well as higher-education pursuits. A major goal of the program was to increase the rates at which participants enrolled in and graduated from institutions of post-secondary education. The summer component was a comprehensive program that took place in July and August. It provided students with intensive academics, including courses in English, math, chemistry, physics, computer science, architecture, space science, foreign languages, psychology, statistics and counseling. Classes were taught by NJIT faculty and high school teachers. Seminars were provided on specific topics offered by community leaders and role models.

The Talent Search Program was an academic-year and summer program designed to encourage students to take an active interest in developing and pursuing academic, career and personal goals. Talent Search provided students with the necessary skills and motivation needed to achieve academic success, graduate from middle and high school, and eventually enter college, trade school or some form of post-secondary training. Middle school students worked to prepare for high school and high school students worked to prepare for college or a career of their choice. It was the intent of the program to have the students enroll in the program as a sixth grader and continue through the program until high school graduation. Talent Search also provided services to students who were interested in obtaining a GED (general equivalency diploma), and assisted students and young adults with reentering high school or college.

The Upward Bound Mathematics and Regional Science Center provided academic enrichment to low-income and prospective first-generation college-bound students to increase the pool of underrepresented groups in the STEM fields. It included a six-week summer program with academic services during the school year. A major goal of the project was to increase the rates at which participants enrolled in and graduated from institutions of post-secondary education by enhancing the students' academic ability and interest in mathematics and science. Research projects with NJIT faculty and mentors were included that allowed students to apply the concepts of physics and mathematics to real-life experiences. The program was designed to:

– Prepare students to enroll and successfully complete advanced mathematics and science courses in high school.
– Encourage students to pursue careers in the STEM fields.
– Provide students with personalized college preparation and counseling services.

As the popularity of robotics in the classrooms grew, robotic competitions increasingly became an after-school activity for students. Deciding to provide opportunities for participation by its students, the Newark Public Schools sought a partnership with NJIT to support this after-school activity and engage in FIRST competitions (For Inspiration and Recognition of Science and Technology). The FIRST Robotics Competition (FRC), for high school students, involves teams competing head to head on a special playing field with robots that they have designed, built and programmed. The FIRST LEGO® League (FLL), for middle school students, involves teams researching a real-world engineering challenge, developing a solution and competing with LEGO®-based robots of their own design. NJIT hosted the FLL competitions for the Newark students.

The high school teams were provided the parts for constructing the robot for the FIRST competition within 45 days, which was not much time. Newark requested help for the high school teams, as for the most part the coaches did not have sufficient knowledge or experience in robotics to guide the teams, and the high schools lacked the shop facilities needed to build the robots. Accordingly, NJIT collaborated with the district by providing a shop technician from an engineering department or physics department to guide the students and provide the necessary facilities. Further training and support for the high school students and their teacher-coaches participating in either the high school FRC or the FLL tournament were provided by NJIT undergraduate engineering students. In addition, summer robotics camps were provided for Newark high school students as preparation for the next FRC competition.

Unfortunately, CPCP was unable to provide a summer robotics camp for the middle school students who participated in the FLL competition. Members of CPCP professional staff served as judges for the FIRST competition hosted at NJIT. While judging the teams in the FLL competition, they were able to observe a major issue that had come up in some of these competitions. It appeared that many of the students on the teams had not acquired the skills and knowledge in science and engineering design prior to constructing their robots. The students simply constructed the robots without any thought to the science and engineering concepts needed to

For the Urban Engineering Program, the first pre-college collaboration with the Newark School District, students built a model city.

complete the assigned tasks. As an example, one team had a robot on wheels. After it started moving, a wheel came off. Instead of trying to see why the wheel came off in order to fix the problem, the students simply put the wheel on again and let the robot go. Shortly thereafter, the wheel came off again. The students simply put the wheel on again, only for it to come off again a short time later. It was concluded that the students didn't know anything about the engineering design that would help them solve the problem. For the students, it was simply a "construction project."

NJIT is no longer involved with FIRST, and it is not known if Newark has continued its involvement. But the FIRST competition still occurs each year.

While initial efforts focused on the secondary school level, it was soon recognized that the effort had to be expanded to the elementary-grade level, thus creating a K-12 continuum to increase and enrich the teaching and learning of the STEM disciplines. Thus, the 1980s became a time of a major focus on the elementary grades.

The programs that focused on science at the elementary level were designed to make science a priority item in the curriculum, so that increased time would be devoted to it in the daily schedule. This was accomplished by demonstrating that an elementary science program can be integrated into the curriculum to complement and strengthen rather than compete with building skills in other disciplines such as English/language arts and mathematics. Today, it is recognized that there is interconnectivity between science, through the Next Generation Science Standards, with the Common Core State Standards in English/language arts and mathematics that reinforces student learning in all these subjects.

The Network for Excellence in Teaching Science (NETS), supported by a comprehensive grant from the New Jersey Department of Higher Education from 1987-1990, provided for intensive professional development in science and mathematics for elementary and middle school teachers. At that time, most elementary schools housed grades K-8, and thus included the middle school grades. During the 1989-1990 school year, grade-specific workshops were provided for 200 teachers (K-8) from eight elementary schools. Each workshop served teachers of a single grade level with a focus on hands-on activities that supported the curriculum. During the 1990-1991 school year, the workshop program was expanded to service 360 teachers (K-6) from 16 elementary schools. In addition, content-based courses in life science, earth science and physical science were provided for seventh- and eighth-grade teachers. Some principals asked for specific professional development programs for their teachers, and this did not always turn out well. While these requested workshops were scheduled on the once-per-month in-service days scheduled by the district, the district also scheduled more general workshops for all Newark teachers. In one middle school, the principal requested monthly workshops for the science teachers, a good idea in theory. Unfortunately, it did not work too well in practice. The success of this type of program requires that all teachers attend all workshops, but the districtwide in-service programs appeared to take priority over any in-service programs scheduled by the principal. This was unfortunate since the workshops for this middle school were designed to meet the specific needs of the teachers, as indicated by the principal, whereas the districtwide workshops were held for all Newark teachers, whether or not they met the needs of the attending teachers. For this middle school, the workshops were discontinued halfway through the year when this problem became apparent and consistent attendance by the teachers was not possible.

These efforts to strengthen and enhance elementary and middle school science and mathematics were true collaborative efforts of NJIT, the Newark School District, the Newark Museum and local corporations and foundations. Newark used its Title II Math/Science funds to support the in-service training of elementary teachers. A three-year grant, from 1991-1994 from the U.S. Department of Education, brought together the resources and expertise of these several sectors for the implementation of a model, innovative middle school learning environment focusing on science and mathematics and the integration of these subjects into the middle school curriculum. The effort involved formal teacher training and in-classroom support of the implementation by personnel from the different sectors.

After-school and summer experiences for elementary-grade students were provided through collaborative relationships with nonprofit organizations. Youngsters from The Leaguers, ASPIRA and the Boys and Girls Club of Newark were provided hands-on science programs and computer classes after school and on Saturday mornings. Collaboration with the New Jersey Marine Science Consortium also provided a Jersey Coast Explorers Program for seventh graders from the Newark Boys and Girls Club.

The Elementary Science Outreach Program (Outreach) was initiated in 1987 as a collaboration with the Newark Public Schools that provided long-term, individualized professional development that would serve as a model of professional development for use in urban areas across the state and nationwide. This was almost 20 years before NSF began funding grades K-12 projects that appeared to replicate this program. The Outreach Program was designed to be a systemic approach to improve urban science and math education through the academic and personal development of teachers, while providing student-centered science learning for the students.

Using NJIT graduate assistants (GAs), the program demonstrated to the teachers that science can be integrated into the instruction of math and communication skills while also building the critical-thinking and problem-solving skills of their students. The teachers were provided with intensive, long-term, in-class support by the GAs, who made weekly classroom visits to model standards-based science instruction while assisting the teachers in the development of their skills in effective science instruction. The teachers were responsible for determining the science topic, based on their curriculum, and the GAs assisted them in the identification of appropriate lessons. The modeling of inquiry-based science instruction by the GAs helped the teachers in the development/refinement of their science teaching skills. Between visits, the GAs maintained contact with the teachers, mainly via telephone, to discuss the next week's class and review the previous class, focusing on strategies that were successful as well as those in need of improvement. Lesson plans were also sent to the teachers prior to the day of the visit to the classroom.

Outreach focused on several grade levels within a small number of schools throughout the academic year, reaching as many as 13 teachers and 300 students each year. Training for the GAs was conducted prior to sending them to the classrooms and continued during the school year through weekly GA meetings and individual meetings with a program coordinator. This prepared the GAs to assist teachers in the classroom by modeling for them inquiry-based science teaching while, at the same time, providing their students with science activities. These sessions also provided the GAs with the program guidelines and classroom expectations.

The personal relationships between the GAs and the teachers promoted the development of individualized strategies that enhanced each teacher's professional development. Because the approach was individualized, each teacher's training within the program was unique and precisely designed to fit his/her individual level of knowledge, comfort, experience and classroom context as he/she moved from the role of assistant to the GA at the beginning of the program to the role of instructor at the end, where the GA then became the assistant to the teacher. Development and implementation of methodologies for the evaluation of both teachers' practices and student performance were integral components of the program.

Evaluation of the Elementary Science Outreach Program required a different direction than evaluations conducted on earlier professional development programs. These evaluations necessitated going beyond simple attitude measures of typical professional development evaluations in order to discover teachers' actual behavior in the classroom. The central instrument of our evaluation component was the observation schedule, which was in the form of a rubric. Based on her four years of experience in the program and the literature on science teaching, Siobhan Gibbons, Outreach Program coordinator, developed a rubric of fourteen classroom behaviors considered to be examples of good science teaching. For each of these items, a scale from one to four of typical behaviors was developed. For example, for the item "teacher's oral participation with the students," teachers were assessed on the degree to which they participated in the actual science teaching as opposed to classroom logistics or discipline only. A teacher who focused only on discipline was a "one" on the scale while a teacher who also talked about the science content, asked questions of students and answered their queries was assigned a "four" on the scale. Thus, detailed information was provided on each individual teacher's starting point and progress as they continued in the program. As a result, CPCP was able to see significant changes in teacher behavior over the course of a school year. For example, teachers overall showed a significant difference in scores from the first week to the end of spring in the following areas:

- The degree to which they were able to bring in everyday examples of science principles.
- Their oral participation in the classroom.
- Their encouragement of their students to provide their own explanations.
- Their use of scientific terms accurately in the classroom.
- Their ability to handle in a useful pedagogical manner their students' unexpected questions.

Other Collaborations

Collaborations in Newark were extended to nonpublic schools as well as schools such as St. Vincent Academy (a high school) and the Gray Charter School (a K-8 school). The Gray Charter School in Newark funded several years of intensive professional development in mathematics and science for their middle school teachers focusing on both content and alignment with standards. The professional development for the teachers included weekly sessions during the school year as well as full-day workshops during the summer for math teachers and science teachers. The training focused on both the implementation of the subject content standards as well as content. The most recent professional development focused on the transitioning to the CCSS-Mathematics. The close relationship with the school was reflected in the invitation by the principal, Verna Gray, to Dr. Kimmel to be the commencement speaker at its 2012 graduation ceremony.

Urban collaborations extended beyond Newark to other urban centers in northern and central New Jersey. The Perth Amboy Scholars Program was initiated by the Perth Amboy School District when it began to send a group of students to the CPCP summer programs. Each summer, the district would pay the fees for the students and provided round-trip bus transportation to NJIT each day of the program. Other districts soon followed this lead, paying for the students' fees and providing round-trip bus transportation each day of the program. CPCP collaborated with other districts including Belleville, East Orange, Jersey City, New Brunswick, Orange, Passaic and Union City.

Meeting the Needs of Students With Disabilities: Project SMART

All students, especially those with a disability, face many challenges when learning concepts in the STEM disciplines. An initiative by Rosa Cano and Diana Muldrow led to a three-year grant from NSF in 1997 for the development and implementation of Project SMART (Science and Math Access to Resources and Technology), a program designed to promote enhanced STEM awareness and provide exposure to elementary and middle school students with special needs as well as their teachers, counselors and parents. Implementation of the program included the addition of Suzanne Berliner-Heyman to the professional staff of the center. At the time she was working toward certification in special education and later earned her master's degree in educational technology.

The program established a professional development model while guiding educators in the development and implementation of programs within their schools and districts that could encourage students of all abilities to study and explore career options in the STEM fields. Teams of regular classroom teachers and special education teachers were provided with in-service workshops during the school year and intensive summer programs, which included interactive seminars focused on content, standards alignment, assessment tools and instructional strategies that accommodated students with special needs, and a practicum experience during the summer with children with special needs to field test and evaluate strategies and curriculum materials and resources.

During the school year, workshops also were provided for school counselors and child-study teams with a focus on:

– Providing information and guidance on educational and career paths for the STEM fields.
– Encouraging and guiding students with special needs to enter and succeed in the STEM fields.
– Including parents as partners in the educational process.
– Becoming successful advocates of children with special needs to pursue education and careers in the STEM fields.

The professional development model developed for this program was intended to promote positive and permanent changes in the academic climate of classrooms, and provide teachers and other service providers with access to appropriate instructional materials, educational technologies and hands-on experiences to ensure full participation in science and mathematics by students with differing abilities. This program was designed to link the many factors that impact teachers' practices and interventions (e.g., the strategies and adaptations for the teaching of science and mathematics). Consistent with the need for inclusive practices, the program was intended to bring general education and special education teachers together for collaborative participation in professional growth activities. Three successive cohorts of urban teachers participated as colleagues and benefited from the model program.

The summer training program emphasized collaborative teaching by general and special education teachers, thereby upgrading knowledge of math and science subject matter to be taught to students with disabilities in practicum, as well as the identification, integration and practice of alternative approaches for teaching math and science lessons. The practicum provided the teachers with a substantial block of time for very deliberate development and field testing of curriculum accommodations and instructional adaptations for improving science and math teaching to children with disabilities. During practicum days, teachers spent their time from early morning through early afternoon in equal portions dedicated to these activities:

– Working in seminars with staff and administration of the project to learn about and discuss various accommodations that might be made to specific lessons and units in math and science.
– Working in small groups to prepare lessons for practicum teaching with children.
– Providing actual instruction with children in student-centered groups, often with two or three teachers working with three to five children.

Suzanne Berliner-Heyman conducts an experiment on measurement with students with special learning needs as part of Project SMART.

– Participating in post-practicum discussion sessions when teacher participants and project staff debriefed the day's practicum to discuss which adaptations or accommodations were helpful and which may not have been successful.

In addition to the aforementioned cycle of activities, teachers submitted lesson plans for each lesson taught and response forms describing successes and problems at the end of lessons. These documents were analyzed at the close of the day by program staff to identify new insights or successful techniques noticed by teachers. The results of these reviews were then used to inform deliberations during the post-practicum discussion sessions.

Through workshops, seminars and practicum activities, teachers planned and carried out particular accommodations and adaptations to improve learning in student-centered small group activities that included children with disabilities. The practicum allowed participants to immediately try out the skills and content acquired in the traditional professional development model with children from special education programs, and reflect and receive feedback prior to returning to the classroom to implement the newly acquired skills and knowledge. As part of the training program, case studies were devised to represent fictional children with specific learning disabilities. In this component, teams of teachers prepared and presented a lesson to the other participants that included adaptations for students with these specific learning disabilities. As each team presented its lesson to the rest of the group, the other teacher teams role played one of the learning disabilities by attempting to do the activity as if they were disabled. This activity placed greater emphasis on the need to individualize instruction for the students.

Recognizing that providing a practicum experience during a professional development program may not be possible due to logistical issues, a mechanism was devised through which this type of hands-on experience could be gained in workshops of variable length, at any location, without the involvement of students with whom the teachers would work. As a result, a portable practicum exercise was developed, in which workshop participants were able to gain the needed hands-on experience through role playing.

A series of scripts was developed, each one detailing a student with a different type of disability. In addition to providing a portable practicum experience, these role-playing exercises provided yet another step in enhancing teachers' understanding of specific disabilities and their ability to accommodate them. It was expected that giving teachers a chance to "take a walk in the shoes" of a specific student would enable them to internalize an understanding of specific disabilities and, as a result, be even better able than they would be without this experience to identify needed adaptations and accommodations. Using the scripts, simulations of students with disabilities were developed to enable teachers to adapt inquiry science lessons for real individual pupils. The simulations were based on actual students drawn from a number of sources and comprehensive descriptions of each student were developed, including age, grade, diagnosis, cognitive profile (strengths and weaknesses in processing skills) and academic profile (strengths and weaknesses in basic skills).

In addition to the intensive summer program for teachers at NJIT, a two- or three-week on-campus summer program for students with special learning needs was held each year in an inclusionary environment. The Science and Mathematics Education for Disabled Students Program, first offered in 1986, was co-directed by Professor Frieda Zames and Professor Michael Lione Sr. of the Department of Mathematics. Most of the students came from schools of teacher participants. About 50 percent of the students were enrolled in grades three to five while the other 50 percent were enrolled in grades six to eight. Categories of classification of these students ranged from orthopaedically impaired to emotionally disturbed. Additional cohorts of students were added to the program in each of the succeeding two years of the project, and displayed similar characteristics as the first cohort.

While providing a practicum environment for the teachers, the program exposed the students to lessons in the STEM disciplines through hands-on problem-solving activities that encouraged them to discover STEM concepts for themselves, and provided experiences that would encourage the student with differing abilities to pursue post-secondary education and careers in the STEM disciplines. The summer program involved a required two-week session and an optional third week for students who desired the extra experience. Interestingly, some of the students who originally opted for only two weeks asked to continue on in the third week (with excitement).

The first two weeks consisted of:

– Working with their teachers (participating SMART teachers) on hands-on math and science activities, computers and communications.
– Field trips to the Newark Public Library (where they were able to apply for library cards in addition to touring the facility), Newark Museum and Barnes and Noble.
– Structured recreational activities with certified physical education instructors every day, including swimming, bowling and games.

The optional third week was structured to mimic the inclusion model, where students received instruction in chemistry, math, communications and computers. It should be noted that some students came back the following summer to enroll in other pre-college programs. One student enrolled in the IFEMME program, with support from a special education teacher, and was a major success story for the program. Another female student was mainstreamed into the Experimental Math Program, with limited support, and did well in the program.

The impact of the program was also reflected in comments from parents and students. Parent comments included:

– "This is the first program where my son has not been picked on or made fun of."
– "My daughter's attitude about school has changed completely. For the first time, she's excited about learning."
– "Every night my son talks about what he did in school that day."

Student comments included:

– "Can I come back next summer?" (voiced by many students), and "Can we come back next week?" (on the last day of the program).
– "I love science."

A University-Based Pre-College Computer Center

After the implementation of the first pre-college program in the early 1970s, the programs expanded by 1980 to six summer programs and an Upward Bound Program, serving over 300 junior high and high school students under the auspices of the newly established Center for Pre-College Programs. The programs continued to introduce the excitement of science and engineering through enrichment classroom/laboratory activities in science and engineering topics and academic reinforcement in mathematics and science. As computers were becoming an important tool in the technological areas, computer science became an essential component in these programs. Computer programming and program design were becoming increasingly important elements of most of the individual pre-college programs.

All computer science instruction for the pre-college programs was held at the University Computing Center, where the students were given a low priority in terms of system access. In addition, all computing was done using batch processing on the institute's computing system, which also required keypunch machines for submitting programs for processing. Due to the limited availability of keypunch time to prepare programs, combined with excessive job turnaround times with batch operations, the number and diversity of topics that could be covered in a pre-college program were severely limited. And part of that time had to be devoted to learning how to use the keypunch machines and setting up the programs for the batch processing. Batch processing required students to spend up to 30 percent of their time keypunching and another 30 percent waiting for their programs to be run; that left only the remaining time to work on the actual programming problem and assignment. This meant limited instruction time and thus made large computers for instructional purposes for secondary school students exceedingly difficult to use as teaching tools. It became apparent that the increased enrollment of students in the programs was making it very difficult to schedule an adequate number of computer classes for all students in the NJIT computer facility. The solution was determined to be the establishment of a computer center under the auspices of the Center for Pre-College Programs.

Thus, the Pre-College Computer Center at NJIT was born. It was the first of its kind at a university in New Jersey and probably in the U.S. William Savin, professor of physics and lead instructor in the Upward Bound Program, was responsible for the donation of 10 DEC WT/78 Word Terminals, an OS/78 system monitor and support software from the Digital Equipment Corporation in late June 1981. This facility for pre-college programs allowed students to use dedicated microcomputers to gain hands-on experience in programming and system operation. It should be noted that 90 percent of students in the 1981 program had no prior experience with computers or programming.

The microcomputers provided an easily accessible system for use by the students. The students were now dealing with a computer system that looked manageable, so that they could understand and see computer system operations and be able to apply this knowledge. Students had immediate contact with the computer – it sat right on the table in front of them so that they could observe each step in the execution of a program. With the disk system, each student had the capability of storing his or her program while it was being run. The easy access to the computer now allowed the students to utilize it to solve problems at almost any time it was needed.

Students study in the Pre-College Computer Center, probably the first facility of its kind at a university nationwide, for K-12 populations.

During the school year, students in the Upward Bound Program continued to receive instruction in the facility in computer programming, program design and computer literacy. Also, the computers were used to provide tutorial services to these students in the basic-skills areas. In addition, during the school year, a course in computer science was provided for different Newark student groups. Classes of students from local high schools came to the NJIT campus one afternoon per week for instruction.

Professional development was provided for teachers after discussions with and inquiries by local secondary school instructors. A course was developed and implemented for teachers through a collaborative effort by NJIT's Division of Continuing Education and the Center for Pre-College Programs. The course focused on microcomputers and their utilization in secondary school education, as well as programming and problem-solving through hands-on experience in the computer center. The topics included introductions to machine organization, computer architecture and computer-aided applications in education. The instruction was kept general due to the diverse nature of the teachers' backgrounds and disciplines.

The Pre-College Computing Center was expanded and re-equipped in 1986 with 20 new computers to replace the old DEC equipment. The center continued its operation into the 1990s, after which the equipment became outdated and sufficient university facilities made it unnecessary to seek funding for new computers.

Contributions of NJIT Student Organizations

The Center for Pre-College Programs (CPCP) has worked collaboratively for a number of years with many of NJIT's student organizations on various activities, workshops, competitions and school visits. Student organizations that have worked with the center have included student chapters of the Society of Women Engineers (SWE), Society of Hispanic Professional Engineers (SHPE), NJIT Robotics Club (NRC) and the American Institute of Chemical Engineers (AIChE).

Over the years, CPCP has received many requests for school visits to the NJIT campus. While on-campus, these student groups often take part in tours, laboratory visits and hands-on activities. SWE and AIChE student members have organized and run hands-on activities for these visits to the NJIT campus. Samples of activities and demonstrations have included making silly putty, shattering a tennis ball with dry ice, and rubber band car races. CPCP has also made connections with neighboring school districts so that AIChE members have been able to go out to the schools to conduct engineering and science activities with students. They have participated in such events as an Engineering Week celebration at the Heywood Avenue School in Orange, the Visiting Scientists Day at the Belleville schools and Estuary Day at Elizabeth High School.

CPCP has hosted various academic competitions, including the TSA-TEAMS competition, the New Jersey Regional Science Olympiad, the Panasonic Creative Design Challenge and the FIRST (For Inspiration and Recognition of Science and Technology) competitions, over the years. In order to run these programs, many NJIT student volunteers, including students from SHPE and AIChE, have been needed to proctor tests or run events at a competition.

NJIT hosted the FIRST competitions for several years. The Newark School District decided to enter teams in the competitions, and partnered with NJIT to support this after-school activity. Specifically, the district needed help for the high school teams, as for the most part the coaches did not have sufficient knowledge or experience in robotics to guide the teams of students. Accordingly, NJIT undergraduate engineering students and members of the NRC volunteered to provide training and support for the student teams and their teacher-coaches. Recently, the NRC attended a robotics night at a local elementary school to represent CPCP and NJIT. They brought with them many robots for the students to observe and in some cases allowed the students to try programming and navigating these robots.

For many years, NJIT students and student organizations have made valuable contributions to the K-12 sector, and CPCP will continue to work with these groups and more NJIT student groups to provide services to local schools.

Career and Technical Education (CTE)

Advanced Manufacturing

CPCP entered the field of advanced manufacturing in July 2008, when it was invited to collaborate on the project Advanced Manufacturing Innovation Partnership, supported by the New Jersey Commission on Higher Education. It was a one-year project carried out by NJIT and Bergen, Camden and Union County Colleges. The main goal of the project was to make available to New Jersey industry the educational material essential for preparing the workforce required by an innovation-driven economy. Under this project, the manufacturing programs in participating colleges were improved and the developed educational material was made available to the partners. As a result of the performed work, a new senior elective MIE course, ME-415 Advanced Manufacturing Processes, was developed and successfully taught during spring 2008.

As a result of the grant, the Center for Pre-College Programs developed and adapted materials to provide an instructional module that could define age-appropriate concepts and be aligned with New Jersey Core Curriculum Content Standards. The instructional units within the module were appropriate both for integration into high school science or technology classrooms, or as stand-alone units of instruction. The modules were introduced to teachers through professional development workshops held at NJIT for science and engineering technology teachers, and at the annual meeting of the then New Jersey Technology Education Association, now known as the New Jersey Technology and Engineering Educators Association. The module included an introduction to manufacturing that provided a history and overview of manufacturing for high school students. The manufacturing process was linked to the inputs by the engineering design process and the outputs determined by the needs and expectations of the consumers. The module included lessons and resources that illustrated manufacturing operations and the process of examining a product, or the process of reverse engineering, to study its components, comprehend how it is produced and synthesize how the product could be modified to better meet the needs of the consumer. Lessons focused on:

– Pharmaceutical industry.
– Manufacture of chocolate chip cookies.
– Baking soda.
– Re-engineering of a cell phone.

CTE – Mechatronics

The image of the old vocational high school is a thing of the past. There has been a national effort to raise the rigor and relevance of CTE in public schools, including New Jersey. Many of the initiatives have been based upon a report prepared by the Council of Chief School Officers Career Readiness Task Force, "Opportunities and Options: Making Career Preparation Work for Students."

CTE has been growing as an alternative pathway to prepare students for good jobs in the workforce. A growing body of evidence has shown the great need for people who are trained in technical skills, according to employers in such fields as manufacturing, IT and health care. Schools across New Jersey as well as the nation have heard these employers and have initiated programs for their students to meet these needs. Many of these schools have partnered with local colleges to provide the expertise and training that the high school might need. Most programs are offering students the option to continue on to college if they wish, but many students will graduate high school, obtain required certifications and enter the workforce.

These career-focused programs of study have been designed to strengthen career and college readiness of high school students by providing them with education and training that combines academic and technical curricula focused on increasing their preparedness for employment in New Jersey industries and, if desired, post-secondary education. These programs are meant to provide students with the opportunities to gain academic and occupational skills by completing the program and graduating from high school, move into a positive placement following high school that can include a post-secondary education, and earn a high school diploma and post-secondary credit toward a two-year or four-year degree from an institution of higher education. Most programs include apprenticeships that allow students to work at an industrial site part time while attending classes on relevant topics and core subject areas.

One such program has been taking place at New Brunswick High School, a traditional high school. The New Brunswick Six-Year High School Diploma/Associate Degree Program, a collaboration of CPCP, NJIT's Department of Engineering Technology and NJIT's Division of Continuing Professional Education, in partnership with the New Brunswick School District, is designed for students who want to prepare for jobs requiring the electrical, mechanical and computer skills necessary to work in manufacturing environments. It is operated under the MechaForce℠ umbrella.

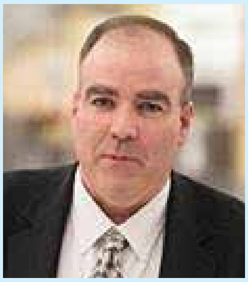
MechaForce℠ is an innovative statewide initiative adapting an apprenticeship/registered internship model tasked to develop a new industry-driven advanced manufacturing curriculum for New Jersey's manufacturing and educational ecosystem. Led by NJIT, MechaForce℠ evolved from the New Jersey Advanced Manufacturing Talent Network, established in 2011, and is funded by such industry leaders as Norwalt Design and Triangle Manufacturing, each contributing an annual fee to its operation and to the support of a director who is devoted to advancing MechaForce℠'s goals. The increased interest in returning Advanced Manufacturing Technology (AMT) to the U.S. has prompted New Jersey to establish focused high school programs that prepare students to either enter the workforce following their high school education or a manufacturing engineering technology undergraduate program. These high school programs coupled with industry-led training are intended to spearhead the specialized education of high school students toward success in the AMT STEM field.

The New Brunswick program started with its first class in fall 2015. In the program, students can earn their high school diploma and an associate degree simultaneously within five or six years, as well as enter a four-year higher-education institution to earn a B.S. degree in engineering technology. Students are able to enroll in college courses through the CPCP Dual-Enrollment Program. This career pathways program provides a clear sequence for integrating educational instruction and workforce development that can lead to appropriate credentials that meet the skill needs of industry. Key program design features include an integrated education program and occupational training through apprenticeships with partner companies. The apprenticeships allow students to work at the industrial site part time while attending classes on relevant topics and core subject areas. The program is part of a STEM Academy in New Brunswick High School, as the study of manufacturing requires an interdisciplinary approach involving science, technology, engineering and mathematics.

K-12 Sector and Post-Secondary Education: Crossing the Border in Computer Science

In the beginning, there was a border between K-12 and post-secondary education with little, if any, connectivity between the two sectors. Then it was soon recognized that post-secondary education should be complementary to the high school education, and must build upon what had been previously learned in high school and the earlier grades. And a K-16 seamless transition came into existence as the disciplines – first in science, mathematics and language

Thomas Phelan



is a licensed civil engineer and a two-time graduate of NJIT, earning a B.S.C.E. in 1993 and an M.S.C.E. in 1998. Phelan knew he wanted to be a civil engineer before he was old enough to even know what a civil engineer was. He cultivated his interest in planning and designing while sitting in the back seat of his family's car during their frequent weekend trips to visit his grandparents in New York. He found the roads and bridges they crossed to get there, along with the buildings of New York City, awe-inspiring. But his greatest fascination was watching the progress of the Meadowlands Sports Complex as it rose out of the marshes alongside the New Jersey Turnpike.

Thanks to a fortuitous visit to his guidance counselor's office during his junior year of high school, he learned about NJIT's Center for Pre-College Programs (CPCP) and his childhood captivation with roads, bridges and tunnels turned into a career pathway. In summer 1985, he enrolled in the university's six-week High School Urban Engineering Program (HSUEP), which laid the foundation for his professional future.

"The program was a marvelous opportunity for an ordinary kid from Kearny to get valuable exposure to STEM fields in a campus setting among a diverse array of fellow students," remarked Phelan.

Harold Deutschman, one of the HSUEP coordinators, later became one of Phelan's favorite instructors in the undergraduate civil engineering program at NJIT. Phelan worked with Dr. Deutschman as an HSUEP instructor for two college summers in the early 1990s. He says he owes his career and all of his professional accomplishments to Dr. Deutschman, Howard Kimmel and the great people who worked at CPCP.

Phelan now serves on the CPCP's Advisory Board and commented, "It is the very least I can do to extend my gratitude to the center and to NJIT, and to cultivate an interest in STEM careers in succeeding generations of young people."

arts, and later in technology education – were extended from the post-secondary level to the secondary- and elementary-grade levels. The Dual-Enrollment Program, described in an earlier chapter, is a good example of the seamless transition where students are enrolled in college courses while still in high school. However, the discipline of computer science was left behind.

In the mid- to late-1990s, Fadi Deek (then professor of computer science and now provost and senior executive vice president of NJIT) and Dr. Kimmel organized several conferences focused on computer science education in the secondary schools, and also carried out a systematic study of issues facing computer science education in the State of New Jersey. The outcome of these conferences and the study was a clear indication that a seamless articulation between high school programs and those at the university level is of critical importance for secondary school educators and would serve as the foundation for implementing a computer science curriculum in the K-12 schools. Subsequently, several New Jersey school districts adopted these recommendations.

Computer science had become an accepted discipline in post-secondary education. However, as of the preparation of this manuscript, computer science education remains a fragmented subject area in the K-12 educational sector in New Jersey. While it is believed that New Jersey is not necessarily representative of the existing situation across the country, it is probable that there are other states at a similar stage of curriculum implementation of computer science in the high schools. The primary issue is that the New Jersey State Department of Education had not and still does not recognize computer science as a discipline in the schools. As a result, there is no teacher certification for computer science in the state and the state core curriculum content standards have not included a set of standards for computer science. The New Jersey content standards have included standards for educational technology. An important outcome of the lack of certification has been that teacher preparation programs in computer science have remained nonexistent in New Jersey. And schools have still been unable to hire teachers who have been certified in computer science and they have continued to assign teaching to teachers of mathematics, science and technology education.

Equally important is the lack of distinction by the Department of Education between computer science as a discipline and educational technology as a tool. There must be a distinction between the technology and the computer science curriculum. In one perspective, computer science must be considered as subject matter and technology should be viewed as a tool that cuts across all subjects. For example, technology is used as a tool in mathematics, science, social science, English and other disciplines, including computer science. It has been this lack of a distinction between them that appears to have been the reason for not having a certification in computer science in New Jersey. The explanation has been that all teachers should be using computers in their classrooms. Therefore, there is no need for certification in computer science.

The end result is that much effort has been put into developing and implementing computer science curricula in the K-12 schools, but it has been unsuccessful in convincing Department of Education administrators of its significance and importance. Unless there is teacher certification in the subject of computer science, and content standards in the subject of computer science, as distinguished from educational technology, there cannot be any computer science curricula or teacher preparation programs in computer science.

K-12 Sector and Post-Secondary Education: Providing Services to NJIT

As mentioned in the previous section, a K-16 seamless transition came into existence as the disciplines – first in science, mathematics and language arts, and later in technology education – were extended from the post-secondary level to the secondary-and elementary-grade levels.

Mentoring Faculty and Instructors to Meet College Accreditation Requirements

What was not described in the previous section was the informative parallel that existed between the attitudes and behaviors of K-12 teachers when they faced the implementation of state content standards, and those of university faculty who were facing new criteria for accreditation of their programs. Commonalities between pre-college and post-secondary instructors included:

- Using the textbook to determine the curriculum and content of the course.
- Considering the course aligned with standards (K-12), or meeting established criteria (undergraduate) if the standards/criteria are topics in the course.
- Identifying instructional objectives or outcomes from the perspective of the instructor, instead of the perspective of the student learner.
- Doing assessments mostly for the sake of doing assessment (for grading purposes) and not using assessment to improve teaching practice or student learning.

But there were also significant differences between the issues facing K-12 and university faculty, primarily due to the nature of the established criteria for the two populations. K-12 teachers needed standards-based lesson plans, in which content standards were aligned with their instructional objectives (i.e., learning objectives) that specified skills and knowledge students were expected to achieve at identified grade levels, with perceived weak or nonexistent connections between them within a grade level or between grade levels. On the other hand, accreditation agencies, such as the Accreditation Board for Engineering and Technology (ABET), developed criteria that specified outcomes requiring the incorporation of a wide range of knowledge and skills that students should acquire over time in several learning experiences (e.g., college courses). In other words, the specified outcomes of agencies, such as ABET, were the skills and knowledge that students should have acquired by the time they graduate from the institution.

Inherent in this description of the differences between the issues facing K-12 and university instructors was the difference between learning objectives and learning outcomes. There has been a definite distinction between objectives and outcomes. Both specified observable behaviors that were measureable. But an objective, such as a learning objective, was meant to specify what students will be able to accomplish, whereas an outcome, such as a learning outcome, specifies what students have been able to accomplish.

Specification of learning objectives and assessment of specified skills and knowledge actually became a substantial part of educational reform of K-12 education in the early 1990s, with the publication of national content standards in mathematics and science, as well as other disciplines. Adoption of content standards by states, informed by the national standards, quickly followed. Since then, NJIT has been working with teachers and public school systems across the state to aid them in aligning their curriculum and instructional practices with the state content standards. Accomplishing changes such as these has been challenging for the teachers. For the most part, curriculum developers and textbook publishers have simply referenced the standards to topics in the published curriculum or textbook. However, curriculum topics aligned to standards alone are not sufficient. As described in an earlier section, alignment with standards also must include the assessment of student achievement of the skills and knowledge defined by the standards. When teachers prepare standards-based lessons, their teaching is focused on student achievement in relation to specific standards.

Since the challenges for university faculty to undertake changes in their syllabi (i.e. curriculum) and instructional methodologies were very similar to those faced by K-12 teachers working toward the alignment of their curriculum and instruction with state content standards and indicators of academic progress, CPCP sought to adapt the processes used to guide K-12 teachers in modifying their teaching practice and lesson planning to work with faculty to change their practices to meet accreditation expectations.

For about five years, starting in 2007, the team of Dr. Kimmel, Ronald Rockland and Levelle Burr-Alexander implemented an effort to extend the K-12 protocol to the post-secondary environment to transform the instructional practices and student learning outcomes for undergraduate experiences, so that students could attain specified learning outcomes linked to course objectives and could be assessed and documented with regard to acquiring the specified skills and knowledge. The assessment was linked to the process of continuous improvement of courses and programs. Each year a series of workshops was provided for faculty and instructors, focusing on preparation of syllabi that included appropriate course objectives, specified student learning outcomes, employed appropriate assessment tools that measured student achievement, and used the information to make appropriate modifications as part of the continuous course improvement.

Emphasis in the workshops was placed on how the process focused on student achievement in relation to outcomes. To demonstrate achievement of competencies expected of students graduating from a program in engineering, for example, it was necessary to identify outcomes for courses that were needed to achieve identified program outcomes. Thus, student learning outcomes, based on program outcomes and course outcomes, had to be continually assessed so that they could serve as the basis for plans to improve programs and curricula in the programs. Improvement in program outcomes depended on changing and improving the curriculum through the course outcomes. This process was summarized in a feedback loop that took into account the vertical levels of assessment activities that must exist at:

– The classroom level.
– The course level.
– The program level.

The workshops demonstrated that an assessment process was only meaningful when the results were used to inform decision-making that would enhance student learning. Further, activities that occur at the level of the classroom were at the heart of the assessment of student learning.

When requested by individual departments, CPCP was able to guide the initiation of a process for several courses that aligned the student learning outcomes to the course outcomes and ABET outcomes, and tied the outcomes to the process of continuous program improvement. Descriptions of outcomes and assessment of student work were used to determine student acquisition of skills and knowledge, and provided suggestions for improving student learning outcomes. While Dr. Rockland worked with his department faculty on a process, Dr. Kimmel worked with interested individual faculty in chemical engineering.

The fact that the process had an impact on the teaching practices of the instructor as well as on aligning expectations of students entering an engineering field with program outcomes was evidenced by the remarks of instructors who realized for the first time that the questions on exams could be used for more than determining course grades for students. Writing of exam questions should be directed by learning outcomes specified for the concepts to be tested. Also, the instructors began the use of learning outcomes and examination of student work for improving their teaching practices.

Other Services

The center responded to faculty and department requests for its services. This included guidance and advice when departments wanted to host pre-college groups on-campus or participate in events off-campus. The center has collaborated with the faculty in the preparation of proposals, usually in the offering of professional development programs and curriculum development in subject areas relevant to the focus of the faculty research. A proposal by Professor Paul Ranky (industrial engineering) and Professor Ernest Geskin (mechanical engineering), Advanced Manufacturing Innovation Partnership, was supported by the New Jersey Commission on Higher Education. The project was meant to develop curriculum materials and courses for high school and college-level programs, with a focus on curriculum for county colleges. For its part, CPCP developed and adapted materials to provide an instructional module that could define age-appropriate concepts and be aligned with New Jersey Core Curriculum Content Standards. Younger faculty who were eligible usually applied for NSF Faculty Early-Career Development (CAREER) Program research grants. One such proposal, by Professor Reza Curtmola and funded by NSF, was on cloud computing. The center provided professional development to STEM teachers on the application of cloud computing to their subject areas.

Guatemala

In 1992, an NCE alumnus, Gil Glass, read an article in an NJIT alumni newsletter about the work of the CPCP. At this time, he was a successful retired businessman, who had earned a B.S. degree in mechanical engineering from NCE. He was now enjoying retirement doing what he loved: mountain climbing, including in the Western Highlands of Guatemala, where he had also visited native villages and noticed a great need for improving education for the children of the villages.

Glass was also on the board of ACCION International, an organization trying to fight poverty by encouraging the economic self-reliance of the working poor. The organization provides basic tools, including training, to be successful with small businesses or microenterprises. ACCION includes a network of programs across Central and South America, with planned expansion into select cities in the U.S. In Guatemala, FUNDAP, an affiliate of ACCION with headquarters in Quetzaltenango, is a private voluntary organization specializing in rural enterprise development that focuses on supporting microenterprises (i.e., small businesses) in the Western Highlands of Guatemala.

At that time, FUNDAP was piloting an educational program in Quetzaltenango called Educacion Integral Para la Vida. The program was meant to be a comprehensive education-for-life skills project to provide children with survival skills and training to become successful microentrepreneurs. It offered literacy training and workforce readiness to the children, ages 10-14, who were underserved by the traditional school system of Guatemala. The children studied math, social studies and home economics in addition to various vocations. These children also received practical tools for self-sufficiency and were equipped with literacy in appropriate business skills to be able to operate a microenterprise. The program was meant to include a microenterprise apprenticeship.

Glass spoke with NJIT's Development Office about CPCP's participation in a visit to Guatemala to observe the program and perhaps provide some expertise. Dr. Kimmel was then approached about this idea and urged to consider it, as Glass was a generous alumnus of the university. Having heard about rebel activity in the country, Dr. Kimmel asked the head of the Development Office if it would pay a ransom if he was kidnapped. The answer was no, but he still agreed to go. He also insisted on having a colleague join him. Dr. O'Shea, who was by then director of science education at Lynchburg College in Virginia, agreed to be a part of this adventure. In addition to his background in education, he was also fluent in Spanish, which Dr. Kimmel considered essential.

So a delegation was organized to visit Guatemala, and the visit took place in April 1993. The trip was sponsored by TACA, the Guatemalan airline. The delegation included:

- Luis Estevez, commercial attaché of Guatemala.
- Hector Mayora, consul of Guatemala.
- Dr. Kimmel.
- Dr. O'Shea.
- Gilbert Glass, businessman and NCE alumnus.
- Libbie Shufro, director of resource development, ACCION International.

The delegation spent the first day in Guatemala City, where members were shown some educational facilities and programs of FUNDAP, and also briefed on the Educacion Integral Para la Vida program. Over the next several days, the delegation was driven into the Western Highlands to finally reach Quetzaltenango. On the road, it observed army patrols at various times, indicating a continuing problem with rebels. Fortunately, the delegation was never troubled by this problem. During the visit, the delegation met with Jorge Gandara, coordinator of projects for FUNDAP and the education program, and was able to visit classrooms and talk with students, teachers and parents in Quetzaltenango and Solala. The delegation found that the program mixed academics with occupations, providing the children with training in trades, such as weaving, sewing and carpentry. The delegation also learned that there were almost 30 high schools in all of Guatemala and that these traditional high schools did not take into consideration

Howard Kimmel and Mark O'Shea were members of a delegation that visited Guatemala in 1993 to observe a microentrepreneurship program for children.

the culture and dialects of the native populations outside Guatemala City. On the last day in the Western Highlands before returning to Guatemala City, the delegation visited Rafael Landivar University, a Jesuit university in the Quetzaltenango region of the country, where it met with faculty and discussed possible collaborations in support of the educational programs of FUNDAP.

On their final day in Guatemala City, in addition to meeting with representatives of the chambers of commerce and the Rotary International, the delegation members also met with the first lady of Guatemala, Magda Bianchi de Serrano, who had run a program in Guatemala City to encourage homeless children to obtain an education. A week after the delegation returned from Guatemala, she became the former first lady, as the government of the country was overthrown by the rebels. Fortunately, this occurred after the visit.

The visit to Guatemala and the educational project were interesting and exciting. Dr. O'Shea and Dr. Kimmel prepared and submitted a report on the visit that included both their observations and recommendations, which would have involved a collaborative relationship between Rafael Landivar University and NJIT, with curriculum and support-material development and a teacher training program provided by NJIT. Unfortunately, funding of the recommendations became a problem, and there was no further involvement with programs in Guatemala.

Chapter 8

Educational Research in K-16: Evaluation and Assessments

Evaluation and assessment have always been important for all programs and activities of CPCP. Its earliest program evaluations of both student programs and teacher professional development programs were typical of that time for such programs – that is, post-evaluations surveyed participants in matters such as successes of the programs and self-reported perceived outcomes of the programs. Implementation of the Elementary Outreach Program required a different direction in terms of program evaluation, a direction that influenced evaluation of later professional development efforts. As described in an earlier section, Outreach necessitated an evaluation plan that went beyond simple attitude measures of typical professional development evaluations in order to discover teachers' actual behavior in the classroom. This approach was taken so that the changes in teachers' behavior could be assessed during their participation in the Outreach intervention, with a focus on teachers' attitudes and personal reactions to the workshops or training they participated in. Evaluation activities were expanded with the implementation of the PrE-IOP program.

This growth in evaluation became the center's entrance into the field of educational research. The center's involvement in educational research activities began in the K-12 programs and later expanded into NJIT programs. The first major activity occurred in 2000 when Dr. Kimmel, Dr. Rockland and Siobhan Gibbons, evaluator for the PrE-IOP project, were tasked with the preparation of a proposal in response to a solicitation from the New Jersey Commission on Higher Education. The proposal required a comprehensive evaluation plan and Gibbons took the lead in preparing the evaluation component of the proposal, which turned out well, since the center received the funding for the PrE-IOP program. Although Gibbons had virtually no training in evaluation and assessment, she became self-taught in these areas while serving as the coordinator of the Outreach Program, for which she had to develop and implement the methodology and instruments for evaluation.

The center's effort in educational research has since been led by Linda Hirsch. Her coming to NJIT is an interesting sidebar. When Gibbons became the evaluator for the PrE-IOP project, she was also a Ph.D. student at Rutgers University studying counseling. During the course of the project, she received help from someone with expertise in educational statistics, who was in one of her graduate courses – Dr. Hirsch. With extra funding available from the PrE-IOP grant, Dr. Hirsch was hired to work with Gibbons. After the PrE-IOP grant ended, Dr. Hirsch became a full-time member of the center staff for program evaluation and related activities.

Evaluation and Assessments

Evaluation and assessment have become a very high priority for CPCP programs. The methodologies have varied due to the variable nature of the different programs, most notably student programs versus teacher training programs. Variation in student or teacher exposure to

A collaboration between CPCP and Newark College of Engineering, PrE-IOP was implemented to enlarge the future pool of qualified high-tech workers.

subjects and experiences further complicates the task.

Evaluation of student programs has evolved over the years. Earlier program evaluations involved post-program evaluations to assess the individual program components and the impacts of the programs on the participants. Various assessment methodologies had been utilized, including student journals, student portfolios and other student work products. For most summer programs, the teachers had been asked to submit documentation outlining student academic advancement in their classes at the conclusion of the summer programs. Samples of student work gave indications of student understanding of scientific or mathematical concepts. For example, in a bubbles activity, students were asked to tell what they learned from the activity. One student commented, “I learned how to make a bubble pipe. I learned that a bubble has gas on the inside and liquid on the outside.” Another student responded, “I learned that matter is something that takes up space.”

Evaluation and assessment have been major components of the PrE-IOP project, and have involved the adaptation, development and utilization of a host of evaluation instruments for the different stakeholders. The center’s experiences with the PrE-IOP project led to the development and adaptation of methodologies and instruments for the student programs that assessed student learning outcomes as well as gains in attitudes toward engineering and knowledge about engineering careers. Accordingly, surveys were developed with attitudinal scales to measure students’ attitudes toward engineers and engineering as a possible career, as well as their engineering skills self-efficacy and level of academic self-confidence, their academic history and their knowledge about engineering careers and pertinent demographic information. Information from the surveys was used to shape program interventions and provided data to determine whether students’ attitudes toward engineers and opinions and knowledge about engineering as a career were changing in a more positive direction.

The evaluation’s survey instruments were developed, validated and utilized over the grant period for both students and their stakeholders: teachers, parents and guidance counselors. Results of the evaluations indicated that knowledge about engineers and engineering as a career increased for middle and high school students whose teachers had attended a PrE-IOP summer workshop. High school students’ attitudes towards engineers and engineering as a career also increased from the beginning to the end of the school year following teachers’ attendance in a PrE-IOP summer workshop.

In addition, teacher instruments were implemented that assessed their concerns about implementing the new curricula, their self-reported preparedness to teach the new curricula, and the programs’ effect on their students. The Teachers’ Concerns Questionnaire (TCQ) was adapted from the Concerns-Based Adoption Model developed at the University of Texas. The TCQ measured teachers’ concerns about implementing new innovations, such as instructional practices or curriculum materials. Repeated administrations of the TCQ were used to identify teachers’ concerns and tracked their changes through the seven stages of concern: awareness, informational, personal, management, consequences, collaboration and refocusing. The Readiness to Teach Questionnaire asked teachers to indicate how ready they were to teach lessons on specific topics covered in a professional development program, ranging from “I would have to start from scratch” to “I can teach a lesson on this topic tomorrow” as responses.

Early on, the center began to assess the long-term impact of the student enrichment programs on the career goals and aspirations of the student participants with follow-up surveys completed by the former participants. Long-term follow-up has been used to ascertain students’ progress in middle school and/or high school, choice of courses in high school, personal development, choice of institution(s) of higher education and major, and career pathway. A computer database was set up to accurately track all pre-college participants.

The important result of any program, teacher training or student enrichment program is the learning outcomes for the students, be it in a summer enrichment program or in the classroom of teachers in a professional development program. While the center had previously assessed teacher learning in the training programs, it had not necessarily impacted student learning outcomes in the classroom. Thus, an important component of the center's work has since become the development and analysis of teachers' standards-based lesson plans, and assessment of student work products resulting from the lessons as a measure of student achievement of learning outcomes in the classroom. Details of the protocol and the utilization of the protocol were given in a previous section.

The assessment of learning outcomes was also extended to the student programs. Instructors of the summer enrichment programs were trained in the use of the protocol to plan standards-based lessons, so that they could write and implement such lesson plans in their classes. Rubric assessments were developed to evaluate the extent to which their students demonstrated the skills and knowledge specified in the lesson plans.

For the center's teacher training programs that have involved practicum experiences with children, several instruments were developed for assessing teacher progress as well as student progress, including methodologies where participating teachers were evaluating the progress of students with special needs that they were working with in the practicum environment. Teacher assessment items included:

– Teacher lesson plans.

– Practicum feedback in which teachers reflected on their practicum experiences. This allowed teachers to assess the practical value of an activity within a model lesson and its feasibility as a lesson for students in their own classrooms.

– Student work.

In workshops where teachers presented their own lessons to their peers, a lesson-presentation feedback was used to obtain teacher opinions about model lessons presented during workshops. It was completed by teachers after they had an opportunity to consider the effectiveness of a model activity for their students after they had directly experienced the activity.

A good number of peer-reviewed publications resulted from the development and implementation of the methodologies and instruments that came from this work, both in journals and conference proceedings. These were well received nationally and internationally, based upon the numerous citations of the work in various publications. Communications have been continuously received from other professionals requesting more information regarding the actual instruments and permission to use them in their own work. One publication that cited CPCP's work referred to the instruments as the "Hirsch instruments."

Educational Research: Undergraduate Research Experience

Research opportunities for undergraduate students have been an important initiative at NJIT. The Ronald E. McNair Post-baccalaureate Achievement Program, funded by the U.S. Department of Education, and the Research Experiences for Undergraduates (REU), funded by the National Science Foundation, continue to provide significant experiences for students to apply and hone their critical-thinking skills as well as their engineering and science skills and knowledge. While these programs are meant to encourage students to pursue advanced degrees in science, technology, engineering and mathematics, very few studies were available to assess this outcome. Professor Angelo Perna, director of the McNair Program, approached Dr. Hirsch to evaluate the programs' impacts. Accordingly, Dr. Hirsch developed an Attitudes Toward Graduate Studies Survey to evaluate the effectiveness of these programs. Students in the summer research programs were asked to complete the survey both at the beginning and end of the summer experience. In addition, a large heterogeneous sample of other students as well as REU students at other universities also completed the survey. The results indicated that students from the summer research programs were more confident in their abilities at the end of the program and had significantly more positive attitudes toward graduate studies. Several peer-reviewed papers describing these studies were published in journals and conference proceedings.

Educational Research: The CCSS Survey Research Project

As part of the Common Core State Standards initiative, the Common Core State Standards for Mathematics (CCSS-Math) was released in 2010 to establish a set of national standards, in part to remedy the perceived inconsistent and inferior quality of many state standards, and also to provide equal academic expectations for all students. Implementation was thought to hold considerable promise to improve student learning. As the CCSS-Math was being implemented in New Jersey, information appeared to be lacking about teachers' knowledge and understanding of the new standards, their concerns and expectations as they transitioned to the CCSS-Math, and the support they would receive from their supervisors, schools and school districts.

As the process of the implementation of the CCSS in New Jersey progressed, a partnership of CPCP at NJIT and members of the education faculty at Rutgers University was formed in 2013 to create a survey to collect information from New Jersey teachers about the CCSS and the new Partnership for Assessment of Readiness for College and Careers (PARCC). Roberta Schorr of Rutgers University served as the principal investigator for the project, funded by the New Jersey Department of Education. She and her team collaborated with the NJIT team of Dr. Hirsch, Dr. Burr-Alexander and Dr. Kimmel. The intent of the project was to ascertain New Jersey teachers' involvement and experience as they and their schools transitioned from the New Jersey Core Curriculum Content Standards (NJCCCS-Math) to the CCSS-Math and the PARCC assessment.

An 82-question survey was developed, and a link to the survey was emailed to 21,000 school personnel throughout the State of New Jersey in December 2013. A total of 1,287 school personnel including administrative and support service staff responded to the survey, but only 923 were identified as classroom teachers. Responses were received from teachers in all 21 counties of New Jersey, with the percentage of responses fairly well proportioned to the size of the county, and with the highest response rate from Essex County. Based on their response to a question about the specific subject(s) they teach – all areas/general education, mathematics, English/language arts (ELA/literacy), science, social studies/history, technical subjects or none of the above – teachers were either presented with further, more specific questions about their professional development experiences and available resources related to the CCSS and PARCC, or the survey was terminated. Dr. Burr-Alexander and Dr. Kimmel collaborated with the Rutgers team in the development of the survey instrument. Dr. Burr-Alexander was part of the research team that conducted telephone interviews with selected responders. Dr. Hirsch took the lead on the data analyses of the survey questions.

Over 300 data tables were generated, many of which required statistical interpretation. Some of the tables were used to generate graphic presentations. Among the 29 general questions asked of teachers and school personnel were what role they saw themselves having in the implementation process and their opinion of the CCSS when implementation of the CCSS began in their school. Overall, the teachers' opinions were not very positive. Most noteworthy is the fact that more than half said that the CCSS "is a good idea, but there still needs to be more planning before using it." Overall, only about 40 percent of the teachers felt they were ready to implement the CCSS, while approximately 45 percent of the responding teachers began implementation of the CCSS during the September 2012-June 2013 school year, and a few indicated that there were no plans to begin implementation as far as they knew. About 48 percent of the English/language arts teachers agreed they felt ready to implement the CCSS, whereas a lower percentage (37 percent) of the mathematics teachers agreed they felt ready to implement the CCSS. Approximately 600 of the respondents (65 percent) indicated that implementation of the CCSS would have some limited or no significant impact on their instruction. Of these, 68 (slightly over 11 percent) were in schools that had not yet begun implementation. These 68 respondents represented the majority (81 percent of 84) that indicated their school had not yet begun implementation, leading to the conclusion that most teachers in schools that have not begun implementation of the CCSS do not really believe it will impact their instruction. One final point of interest was the response with respect to the PARCC assessment. A very small percentage of the teachers agreed that they believe their students were prepared to be successful on the new PARCC assessment, with the percentage of mathematics teachers being the lowest (6.8 percent).

A major issue regarding the implementation of the CCSS was the manner in which it was carried out. For example, a comparison of the CCSS in mathematics with the old New Jersey CCCS in mathematics shows the following:

- Some standards were moved from higher grade levels to lower grade levels.
- New standards were introduced in different grade levels.

The CCSS were implemented in grades K-12 simultaneously. This caused major problems in terms of learning progressions. For example, a student going from sixth grade to seventh grade missed learning opportunities for the new standards introduced in grades K-6, or for those standards moved from grade seven or above to grades six and below. Due to these shifts and additions in the standards, a more appropriate strategy to implement the CCSS would have been to do it by single or small groupings of grade levels to be carried out over several years. Then students would have had the learning opportunities for these standards.


COLLEGE PROGRAMS

Chapter 9

Future Directions: The Journey Continues

The Center for Pre-College Programs (CPCP) is not, nor has it ever been, a "static" entity. Rather, it has become, and should remain, a "vibrant, living" entity that will continue to flourish and grow. In the 35-plus years since the creation of the center, breakthrough initiatives have led to many accomplishments.

But in looking back at what has been accomplished and in looking toward the future, CPCP can see that there are still challenges to be met, and new challenges that will arise as time moves on. Some of these challenges are those that have been addressed in past initiatives, as described earlier, but continue to be ongoing and still require attention. Most notable would be:

- Increasing minority participation in STEM.
- Support of students to achieve high academic standards.

The center should continue to address these two challenges through programs with students, as well as with professional development for teachers and technical assistance and services to schools and school districts.

The center should continue to maintain and promote itself and the university in the national network of university and K-12 educators through presentations at professional conferences and publication in refereed journals.

Other challenges have come to the forefront more recently and would require a greater focus to successfully meet. These challenges are not discussed in any particular order, as they are all important. In the discussions that follow, each one may not be considered in isolation from the others. That is, there is overlap among these challenges, and so their interactions will be part of the discussion.

- Clarifying college and career readiness.
- Addressing the challenges faced by students transitioning from high school to post-secondary education and careers, e.g., the Central High School program.
- Expanding the pathways for students in high school (CTE).
- Promoting STEM as an interdisciplinary approach to education, and providing guidance to school districts.
- As a center for education, continuing to expand the cross-over between K-12 and post-secondary education.
- Continuing initiatives in educational research, e.g., adapt post-secondary development to K-12 activities and K-12 development to post-secondary activities.

Clarification of College and Career Readiness

The Common Core State Standards (CCSS) continue to be a topic of discussion and concern. In the evolution of standards movement over the past 20 years, it had always been the accepted principle that standards should specify the minimum skills and knowledge that students should acquire at each grade level. This appears to no longer be the principle in the development and implementation of the CCSS. The standards have been labeled as College and Career Readiness Standards for students. Yet, according to findings of the American College Testing Inc., the CCSS have failed to prepare students for college. In addition, there appears to be a disconnect between what is emphasized in the common core and what some college instructors perceive as important to college readiness. In some circles, it is believed that the transition between secondary and post-secondary education has become a difficult process due to a disconnect that exists between secondary and community college education. High school students should be made aware of the academic reality of college life. When leaving high school, they should have learned how to learn.

Labeling the standards as college and career readiness cannot be considered consistent with the status of the diversity of educational opportunities made available to students. For example, the Career and Technical Education (CTE) high schools and programs have provided opportunities for students in which they have been given the option of entering the workforce with the requisite skills and knowledge for success, or pursue post-secondary education. College need not be a requirement for a career in the workforce. It should also have been apparent to those who developed the CCSS that the two pathways would require the specification of different skills and knowledge in the standards. One such CTE program has been described in an earlier section.

It should be recognized that the full meaning of college and career readiness encompasses a body of knowledge and skills that extend beyond academics. A significant aspect of this problem of alignment of K-12 assessments with college readiness is the dependency on the high-stakes testing for the CCSS. The use of PARCC assessments to gauge college and career readiness fails to recognize that one or two tests cannot measure such a complex attribute as college and career readiness. This carries forward the same flaw as the CCSS. Indeed, the debate on how to measure college and career readiness is ongoing. These attributes, or what should be considered necessary for success in the workforce, are not actually included as part of the standards and cannot be assessed by tests such as PARCC. For students to be ready to enroll in a post-secondary institution or enter the workforce, they will need to have, in addition to proficiency in academic content, important skills such as:

– Good study habits and time management.
– Good organization and being detail oriented (i.e., conscientiousness).
– Problem-solving/critical thinking.
– Ability to employ technology tools to produce and present relevant and accurate information.
– Ability to interact with others face-to-face and through written communication.

The center is well-positioned to pursue the question of what it means to be college and career ready. Through its student programs, the focus has always been on college and career readiness, as well as the academics, providing students with an introduction to some of those attributes considered essential for success. The center can now seek to determine which attributes are considered most essential for success at the college level. Such an initiative will require an expansion of the cross-over between the K-12 sector and post-secondary education, since this issue has to be viewed from both sides. The center's capacity for pursuing educational research can provide the vehicle for surveying K-12 teachers, college instructors and faculty, and employers to ascertain their perspectives on the meaning of college and career readiness and what it will take for the preparation of students for success. New methodologies and effective practices can result in improved college and career readiness and persistence, retention, academic progress and college degrees, particularly for those who are underrepresented, underprepared or from low-income backgrounds, which can be field tested in the center's student programs. Further, the center can use its extensive experience of providing professional development for teachers and technical assistance to schools to guide teachers in the implementation of these new methodologies and effective practices via the three interrelated components of teaching and learning: instruction, curriculum and assessment. The outcome should be well-prepared students, entering post-secondary institutions and/or pursuing STEM-related programs of study.

Transitioning From High School to Post-Secondary Education

As pointed out in the previous section, the transition between secondary and post-secondary education has become a difficult process for high school students. A significant number of new college students still arrive on college campuses lacking the necessary academic skills in mathematics and/or language arts to perform at the college level. Language arts college instructors appear to be working with students who have not been fully prepared for college writing, because there are more advanced levels of reflection and thinking at the college level than simply summarizing existing ideas as required by source-based writing on standardized tests. Also, inadequate development of skills and knowledge in mathematics has resulted in proficiency levels that hinder the academic achievement and college readiness of secondary school students.

Post-secondary institutions have been addressing this problem with extensive remedial programs designed to strengthen students' basic skills. Remedial education programs have usually included support services in addition to pre-college-level coursework, both of which are designed to get underprepared students ready for college-level work. Despite this proliferation of remedial courses provided by colleges, the problem persists. Studies on the effectiveness of remedial education have produced mixed results.

The center has recognized that the challenge of college readiness in academic content must be addressed before students enter post-secondary institutions. As part of initiatives leading to a cross-over between the K-12 sector and post-secondary education, there needs to be an alignment of content, instructional practice and assessment strategies for college preparedness in the subject areas, so that the teaching and learning at the high school level is compatible with those of post-secondary institutions. The center has initiated approaches that could lead to improved outcomes for students, particularly for those who are underrepresented, underprepared or from low-income backgrounds.

The collaborative partnership with Newark Central High School (described earlier) led to the development and implementation of a program in which Central High School students would be enrolled in the NJIT pre-calculus course (4 credits) on the NJIT campus during the last periods of the high school day. The program created a classroom environment for the students that was conducive to a positive learning experience, as they came to understand the requirements for success in a college classroom and were able to enter and succeed in college without the need for remedial courses. This program should be continued and refined so that it can serve as a model to be replicated at other high schools in Newark and other urban areas.

For long-term impacts, the center has reached out to teachers and schools to provide professional development and technical assistance to the middle schools as well as the high schools. For example, a program can be provided with a focus on selected content skills, knowledge and practices for CCSS-Math related to the high school level in the domains of number, quantity and algebra that could bolster effective learning and instructional practices; this could demonstrate how these skills and knowledge are aligned with the expectations in the college-level courses. Such professional development programs could be supplemented with meetings of the high school teachers and NJIT math instructors for discussion and reflection on the alignment of the high school mathematics with college-level mathematics. Together they can develop the most promising approaches to improving outcomes for students.

Expanding the Pathways for Students in High School (CTE)

The phrase "college and career readiness" implies that all students MUST attend college. Not all students benefit from college or are interested in attending college. Career and Technical Education (CTE) has been growing as an alternative pathway to prepare students for good jobs in the workforce. There is a growing body of evidence of the great need for people who are trained in technical skills, according to employers in such fields as manufacturing, IT and health care. CTE programs also provide for an effective delivery of integrated science, technology, engineering and mathematics (STEM) teaching and learning. Schools across New Jersey (and nationally) have heard these employers and have initiated programs for their students to meet these needs. Many of these schools are partnering with local colleges to provide the expertise and training that the high school might need. Most programs offer students the option to continue on to college if they wish, but many will graduate high school, obtain required certifications and enter the workforce.

The partnership of the Center for Pre-College Programs and the Division of Continuing Professional Education at NJIT has led to a collaborative effort to offer high school students the opportunity to pursue careers in Advanced Manufacturing Technology (AMT) and Mechatronics. The current focus of this partnership is addressing the need for high school students to be college and/or career ready in the AMT field immediately after high school, with appropriate industrial certification in advanced manufacturing, and/or pursuing a post-secondary degree in engineering or engineering technology. The center should continue to partner in the development of the New Brunswick AMT program within a traditional high school, so as to be in the position to document and then replicate and support the program in other high schools in the State of New Jersey.

STEM Education

As previously described, an interdisciplinary approach to STEM has been the hallmark of the center's programs for students, as well as technical assistance and teacher professional development in K-12 schools. But the challenge is still there to provide all students with the opportunity to acquire the core knowledge and skills necessary to solve difficult problems, gather and evaluate evidence, and make sense of information available from varied print and digital media. The center should continue to meet this challenge by developing a greater understanding of these issues along with strategies to address them, and promoting effective practices that provide all students equal opportunities to acquire STEM knowledge and skills, so that they will be well-prepared when entering post-secondary institutions to pursue STEM-related programs of study and/or careers in a STEM field. In this cross-over between the K-12 sector and post-secondary education, all efforts should be made to involve NJIT faculty and students in the preparation of the K-12 students to successfully transfer to a post-secondary institution.

Chapter 10
Concluding Remarks

This story began with how Dr. Kimmel started his career as a member of the chemistry faculty at Newark College of Engineering in 1966 (later to become NJIT in 1974), with the vision of being a facilitator of learning for undergraduate and graduate students, and scholarship with an active research program. Then in 1974, he was invited to be part of a summer program in science and engineering for urban middle and high school students as a co-director and teacher of energy concepts and environmental impacts. He found this to be an exciting, rewarding and enjoyable experience. Within a couple of years, he found that while there were many university faculty conducting active scientific research programs, there were relatively very few focusing on the needs of K-12 students and teachers. And their needs in science, math and engineering were great. It was then that he made the decision to not continue his research program so that he could devote his time and energy to the pre-college sector, while continuing his other responsibilities as a member of the university faculty. He never looked back on this career change.

Now when he reflects back on the beginning of this journey, when he started interacting with middle school and high school students and teachers in 1975, he had no inkling of what was to come in the next 40 years or so at NJIT. As he looks back after his retirement in 2012 as a member of the faculty for 46 years, as well as his retirement from formal involvement in pre-college programs after 41 years, he is amazed at what has been accomplished in the K-12 sector since that first experience with the students in the Urban Engineering Program. And while much has been, and will continue to be, accomplished by the center, it could never have been done without the tremendous efforts and dedication of the many NJIT faculty, administrators, students, teachers and center staff who helped provide these pre-college students with the enrichment experiences and motivation to succeed.

It is a legacy that must be shared with all who have made their contributions to its success.

AFTERWORD

By Jacqueline L. Cusack

Executive Director
Center for Pre-College Programs

Upon my appointment to the position of executive director, I learned that a written record of the rich history of the Center for Pre-College Programs' (CPCP) early beginnings and development did not exist and that Howard Kimmel was the primary repository of the information. It was then that I began urging him to document that history, not solely for record-keeping purposes, but also for those who are engaged in educating our youth and seek to impact their education in the fields of science, technology, engineering and mathematics (STEM).

Dr. Kimmel's account of CPCP's history is a case study in how partnerships between and among elementary and secondary schools, higher education institutions, private sector organizations and corporations all combine to enrich the lives of students. Not only do students benefit from these relationships, but the perspective of those who serve them – the educators – is enhanced by the connections that support and inform STEM education. As articulated by the American educator and former U.S. Commissioner of Education Ernest Boyer, "… becoming well educated … means discovering the connectedness of things. Educators must help students see relationships across the disciplines and learn that education is a communal act, one that affirms not only individualism, but community."

CPCP is one example of how student success in STEM education leads to student success in our communities.

Boyer, E. (1995) The Educated Person - From the 1995 ASCD Yearbook p.16 – "reprinted by permission."
ASCD (The Association for Supervision and Curriculum Development)

Appendix A

The Center for Pre-College Programs: Mission and Goals and Objectives

"Inspiring young minds for college access and success in science, technology, engineering and mathematics (STEM)."

Mission Statement – New Jersey Institute of Technology, through its Center for Pre-College Programs (CPCP), shares the state's vision for strong science, mathematics, engineering and technology education throughout New Jersey, and applies the knowledge and resources of New Jersey Institute of Technology, in partnership with teachers, schools and other stakeholders, to help make this vision a reality. The mission of the center, fully incorporated into NJIT's community mission, is to provide all students with equal access to high-quality STEM education, mentorship activities and peer support, allowing underrepresented groups to see the rewards that STEM careers can bring, and to provide all children the opportunity to learn and meet the high academic expectations of the New Jersey Core Content Standards.

Goals and Objectives – CPCP goals are to:

- Establish and coordinate academic programs to serve elementary, middle and secondary school students and teachers.
- Provide leadership in the development and assessment of STEM education.
- Improve the quality of education in urban school districts at the elementary, middle and secondary levels by focusing the efforts and expertise of available faculty and staff toward that end.

The center meets these goals by implementing the following objectives:

- Provides students with intensive academic enrichment programs in STEM areas, not available in elementary, middle and secondary schools, to academically prepare them to pursue careers in STEM.
- Provides mentorship and peer support activities to students to encourage them to view careers in STEM as a meaningful and realistic goal, while also supporting them in their quest for a career in these fields.
- Provides professional development and training programs for K-12 educators to help ensure they are able to align their teaching practices with the state content standards, and develop and implement effective standards-based lesson plans, in order to strengthen and enhance the quality of elementary and secondary school teaching and learning.
- Provides New Jersey teachers, schools and school districts with guidance and support in curriculum development and adaptation, standards alignment, curriculum resources, instructional strategies, assessment of student learning aligned with state/ national standards, and evaluation services.
- Develops resource materials, classroom lessons and practices, laboratory experiments and demonstrations for use in the schools and to disseminate the information to teachers and students for the advancement of knowledge.
- Provides workshops to students' families to increase their participation in the educational process of their children in order to support them through the barrage of negative peer pressures that will distract them from achieving their full potential.
- Ensures adequate financial support and resources for approved programs.

Milestones/Outcomes – Through all pre-college initiatives, the center establishes effective academic and social learning communities for all project stakeholders, students, teachers and families in the targeted communities to maintain the interest of all participants in STEM areas.

Student Outcomes – Students who participate in NJIT's pre-college programs are better prepared to pursue higher education opportunities in STEM fields than their peers. The following outcomes are anticipated and observed:

– Increase in grades in standardized test scores, especially in math and science.

– Increase in the number of students enrolling and completing advanced placement courses in high school.

– Increase in student knowledge about STEM careers, interest in pursuing those careers and confidence about his/her ability to pursue STEM careers.

– Increase in the number of students actually pursuing and completing STEM careers (as per long-term follow-up studies).

– Positive reports from parents of student confidence and interest.

Teacher Outcomes

– Improved teaching practices and organizational models that lead to more equitable and inviting STEM educational environments in K-12.

– Learned and implemented experiences and interactions in informal and formal educational settings that encourage interest and performance of all students in STEM.

– Increased knowledge of the process of institutional change required to achieve more equitable and inviting STEM educational environments in K-12.

Parent/Guardian/Family Outcomes

– Increase in knowledge about STEM careers.

– Increase in knowledge about academic courses in high school necessary to pursue and complete STEM careers.

– Increase in parents' support for STEM learning.

Appendix B

The Center for Pre-College Programs: Its Beginnings and Its Growth
A Chronology of Events (1970-2012)

The Beginning
Student Program: 1970 – High school Urban Engineering Program for 40 students, funded by NSF and directed by Harold Deutschman and Su-Ling Cheng. Focus on urban planning and transportation.

First Expansion
Student Program: 1974 – Became Urban Engineering Program for 40 high school students, and Introduction to Urban Engineering for 40 middle school students.
Funded by NSF, GE and Exxon and directed by Su-Ling Cheng, Harold Deutschman, Howard Kimmel and John Droughton.
Focus extended to include energy and environmental issues.
Publication of "Urban Crisis."

Professional Development for Teachers: 1975-1979 – Energy and Environmental Technology for Secondary School Teachers, a year-long course funded by NSF and directed by Howard Kimmel.
Interdisciplinary approach taught by Howard Kimmel and Reginald Tomkins (chemical engineering and chemistry), Manny Perez (mathematics) and Achille Capecelatro (physics).

1979 – Howard Kimmel was an invited participant in a Practitioner Conference on Energy Education at Rockford College, Ill., in December. Conference objectives: Develop recommendations for public interest groups, industry, and federal and state agencies.

1979 – Formal establishment of the Center for Pre-College Programs (CPCP) by the NJIT Board of Overseers under the leadership of Howard Kimmel and Harold Deutschman. The Board of Overseers created an Industrial Advisory Board for the center under the leadership of a chairman, Gerry O'Loughlin of New Jersey Bell, and a vice chairman, Michael Leone Jr. of New Jersey Bell.

1983 – Rosa Cano and Diana Muldrow became the first members of the CPCP staff.

1980s – Growth – A Period of Somewhat Random Growth

Milestones
1985 – ASEE – Vincent Bendix Minorities in Engineering Award.

1989 – Hosted the National Conference on Pre-College Education for Minorities in Science and Engineering.

1981 – Establishment of the Pre-College Center Computer Center, with 10 computers from DEC.

1984 and **1986** – Expansion and re-equipping of the Computer Center with 20 new computers to replace the old DEC equipment, funded by the Victoria and Turrel Foundations.

Student Program Initiatives
The two Urban Engineering Programs continued.
1980 – FEMME-9, first program funded by NJIT, Director Dana Levine.

1980 – ChIME (Chemical Industry for Minorities in Engineering) program for high school students, funded by ChIME organization and industry, implemented by L. Bryce Anderson and directed by Reginald Tomkins.

1985 – Introduction to ChIME for seventh and eighth graders, Director Reginald Tomkins.

1980-1982 – Minority Research Apprenticeship Program for High School Students, funded by the U.S. Department of Energy.

1981-1992 – Pre-Freshmen Engineering Program (PREP), funded by the U.S. Department of Energy.

TRIO Programs came to campus in 1989, and at various times have had:
– Upward Bound Program.
– Upward Bound Mathematics and Regional Science Center.
– Talent Search Program.
With several different administrators, including William Freeman, Henry McCloud, Levelle Burr-Alexander and currently Monique Paden-Hutchinson.

1980s – Perth Amboy Scholars – Summer program participants funded by the Perth Amboy School District (including bus transportation). First district to provide such support.

1983-2002 – Experimental Math, Science and Communications, initially funded by the Victoria Foundation, Directors Professor Jay Kapraff and Professor Rose Dios.

1986-1996 – Science and Mathematics Education for Disabled Students, initially funded by the New Jersey Department of Higher Education, Directors Professor Frieda Zames and Professor Michael Leone Sr.

1987-1989 – Jersey Coast Explorers, funded by the New Jersey Department of Higher Education and Dodge Foundation (1989).

High School Scholars Program:
– Integrated Calculus/Physics (on-campus) – 1970s.
– College Chemistry (on-campus) – 1979.
– Physics I (ACCESS NJIT) – 1980s.
– Calculus I (ACCESS NJIT) – 1980s.
– Chemistry I and II (on-campus and ACCESS NJIT) – 1990.

Teacher Professional Development Program Initiatives

1982 – Faculty Development Program for Elementary Grade Teachers, funded by U.S. Department of Energy.

1982-1985 – Energy Education In-Service Workshops, funded by PSE&G.

1983 – Energy Education for Secondary School Science and Social Studies Teachers, directed by Howard Kimmel and John O'Connor (Humanities Department), funded by NSF.

1980s – Site leader for U.S. Department of Energy's Citizens' Workshop on Energy using the Energy Environment Simulator.

1983 – In-Service Program for Chemistry Teachers, funded by Woodrow Wilson Foundation.

1985 – Network for Excellence in Science Teaching (NEST), funded by the Department of Higher Education.

1984-1987 – Science Curriculum Improvement Project, with focus on marine sciences, funded by the New Jersey Department of Higher Education. Involved face-to-face summer and academic-year workshops and electronic communications.

1988-1992 – International Network for Education in Science Teaching (INEST), included a three-year grant from the Hitachi Foundation that extended to Hawaii and Japan.

1987 – Urban Elementary Science Outreach, sent graduate assistants into elementary classrooms in Newark to model the teaching of science to the teachers while providing science instruction to the students, almost 20 years before NSF issued its first solicitation for a GK-12 Project.

1989 – Collaborated with Fadi Deek to host a Conference of Secondary School Teachers of Computer Science. Concern that New Jersey does not certify teachers of computer science.
Guided the formation of a New Jersey chapter of the Computer Science Teachers of America.
Participated in the review of computer science curriculum to be published by Association for Computing Machinery.

1990s – Growth – A Period of the Beginning of Evolutionary Growth

Milestones

1990 – At the request of the New Jersey Department of Higher Education, Howard Kimmel and Reginald Tomkins prepared and submitted a report, "Feasibility Study and Planning for Early Entry Programs."

1990 – The Center for Pre-College Programs recognized by the American Association of State Colleges and Universities for the center's exemplary pre-college program model for recruitment and retention of minority students and its cooperative efforts with the public schools.

1990 – Invited to present program at the NACME FORUM '90 in Chicago, "Reaching Out to the Inner City."

1993 – ASEE–CENTENNIAL MEDALLION for Significant Lasting Impact on Engineering Education.

1993 – Member of Guatemala delegation for on-site visits and to discuss collaborative efforts to help improve the literacy and job skills of children in the native villages of Guatemala. Members of the delegation included: Howard Kimmel, Mark O'Shea, Gilbert Glass (ME, NCE alumnus), Libbie Shufro (ACCION International), Luis Estevez (Guatemala consulate and associate dean of Universidad Rafael Landivar). A report was submitted making recommendations for the education and training of youngsters in mountain villages.

1994 – Presented invited workshop at Ninth Annual Conference of NAMEPA.

Student Program Initiatives

1989-1996 – Young Scholars Program–Research in Environmental Waste Management for students entering grades eight and nine.

1992-1994 – Summer Science Camps for sixth graders, funded by the National Science Foundation.

1992-2007 – Engineering Prep Bridge Program introduction for high school students.

1998-2006 – Project GRAD-Newark, included a four-day residential component at Sandy Hook. Armand Berliner, professor of mathematics, was the director of this program.

NSF-funded programs for female students:
Creation of the Women in Engineering and Technology FEMME Program.
Introduction to FEMME – sixth graders.
FEMME Continuum – seventh graders.
Bridge to FEMME – eighth graders.
FEMME9 Program became the Sr. FEMME Program – ninth graders.

Continuing Programs:
1997-2004 – The Urban Engineering Programs became the Urban/Civil Engineering Summer Institute for ninth graders.

1974-2005 – Introduction to Urban Engineering.
Experimental Math, Science, Communications Program (EMP) – summer.
Sr. ChIME until 1994.
Jr. ChIME.

1996-1998 – Science and Math Education for the Disabled, sixth- to eighth-grade students – summer.
TRIO Programs – summer and school year.

1998-2004 – GEAR UP Partnership.

The Beginnings of the Academy and Dual-Enrollment Programs:

1989 – High School Scholars Program continued, as the College Chemistry Program was carried by ACCESS NJIT as well as on the college campus.

1991 – Summer Academy was established, with courses in:
Architecture
Chemistry
Computer and Information Science
Pre-Calculus
Calculus
Tuition scholarships for the academy were provided by corporations for high-need students.
Project SEED – Summer research program for high school minority students supported by American Chemical Society.

Competitions
1984 – New Jersey Chemistry Olympics.

1989 – JETS TEAMS Competition, later became TSA TEAMS Competition.

1991 – Panasonic Creative Design Competition/Challenge.

Teacher Professional Development Program Initiatives
Implementation of Comprehensive Teacher Training and Curriculum Improvement Programs.
Implementation of National and State Standards, began the need for teacher professional development to align classroom instruction with the standards.

1998-1999 – Training programs on standards for all Newark teachers in grades one through eight.

1996-1999 – GOALS 2000 – Professional development project for teachers in Harrison and Union City, funded by the New Jersey Department of Education.

1991-1994 – Partnership for Science and Mathematics Learning in Urban Middle Schools, funded by the U.S. Department of Education.

1992 – Elementary and Middle School Teacher Professional Development, funded by Exxon Chemical-America.

1994-1996 – Hazardous Waste Management for Middle School Teachers, summer workshops, funded by NSF.

1995-1998 – SMART Program for teams of regular classroom teachers and special education teachers, funded by NSF.

CPCP IAB
Retirement of Gerry O'Loughlin as chair and Michael Leone Jr. as vice chair.

1997 – Michael Bober assumes the position of chair and William Lewis as vice chair.

1994-1998 – Funding from NSF establishes a Statewide-Systemic Initiative (NJSSI) in New Jersey which provided:
– Professional Development Network for K-8 teachers.
– Standards-Based Curriculum and Assessment Implementation Program.
NJIT was a host site for NJSSI and Howard Kimmel was site leader and member of the Senior Project Leader Group of NJSSI.

2000-Present – Growth, the Systemic Approach

Milestones
2004 – A full-time evaluator for programs, Linda Hirsch, was added to staff.

2012 – Howard Kimmel was invited to be commencement speaker for the Gray Charter School Graduation.

Student Program Initiatives
TRIO Programs continue.
Women in Engineering and Technology FEMME Program – a different focus each year.
Implementation of Environmental Engineering FEMME – fourth grade.
Introduction to FEMME – sixth grade.
Aeronautical Engineering FEMME – fifth grade.
FEMME Continuum – seventh grade.
Mechanical Engineering FEMME – sixth grade.
Bridge to FEMME – eighth grade.
Chemical Engineering FEMME – seventh grade.
Sr. FEMME Program – ninth grade.
Biomedical Engineering FEMME – eighth grade.

Coed Programs:
Environmental Science and Engineering Program (ESEP) – fourth grade.
Aeronautical Engineering Program (AEP) – fifth grade.
Pre-Engineering Program (PrEP) – sixth grade.
Explore Careers in Technology and Engineering Program (ExCITE) – seventh grade.
Medical Robotics (MEDIBOTICS) Program – eighth grade.
Introduction to Chemical Industry in Minorities Engineering Program (IChIME) – seventh and eighth grades.
2009–continuing to the present – The Bernard Harris Summer Science Camp – sixth, seventh and eighth grades, funded by ExxonMobil.
2003 – Algebra Prep Program, a summer program for eighth and ninth graders who will be enrolling in Algebra I in the fall.
A Medibotics Program for Newark eighth graders, funded by the AT&T Foundation, implemented in spring 2012.

The Urban/Civil Engineering Summer Institute and the Engineering Prep Bridge Program evolved into:
Fundamentals of Physical Sciences (FPS) – ninth through eleventh grade.
– Chemistry.
– Physics.

The High School Scholars Program and the Summer Academy evolved into a:
– Dual-Enrollment initiative of the New Jersey Department of Education in 2004.

Academy providing academic-year and summer college courses at NJIT.
– Twelfth Grade Options Program providing courses at New Jersey high schools.

– **2009-2012 –** A Dual-Enrollment Program, funded by the New Jersey Commission on Higher Education, provided an on-campus program for Newark students and an off-campus program at New Brunswick High School.

– **2009-2015** – Pre-Calculus course for Central High School seniors held at the NJIT campus.

A robotics partnership with NPS was initiated in 2004.
– **2004-2006** – Robotics Summer Science Camp.

– **2004-2010** – Support of student teams competing in High School FIRST and FIRST LEGO® League.

Competitions
– The Panasonic Creative Design Competition/ Challenge, the NJ Chemistry Olympics and the TEAMS competition continue. Sponsorship of the TEAMS competition changed from JETS to the Technology Student Association (TSA).
– NJIT became the Northern Regional Site for the New Jersey Science Olympiad.

Teacher Professional Development Program Initiatives
"Leaders of Learning" – Providing services to schools and districts in:
– Professional development.
– Aligning classroom practice with standards.
– Enhancement, modification, development of curriculum.
– Student assessment.

2001-2004 – Pre-Engineering Instructional and Outreach Program (PrE-IOP), funded by the New Jersey Commission on Higher Education.
Start of the synthesis of professional development, alignment of classroom practice with state standards, curriculum review, development and modification, and student assessment, with focus on different fields of engineering: biomedical engineering, chemical engineering, civil engineering, electrical engineering and mechanical engineering.

2008-2009 – Development of curriculum module in manufacturing engineering and professional development.

2003-2004 – Camden Middle School-Newark, professional development in science.
2007-2009 – Harrison Middle School Mathematics Program (INCLUDE), funded by the New Jersey Department of Education, professional development for middle school mathematics teachers and alignment of curriculum with New Jersey Math Content Standards.

Various professional development programs on-campus and at district locations:
– AT&T summer workshop on robotics.
– STEM workshop at Vernon Township High School.
– **2009-2014** – Math and science professional development for Gray Charter School-Newark.
– **2012-2014** – AT&T professional development on CCSS-Math for middle school teachers in Belleville and New Brunswick.

2006-2010 – Medibotics, funded by NSF.

2006-2012 – RET Program, funded by NSF.

2011-2013 – Virtual Medibotics, funded by ExxonMobil Foundation.

2013 – Formation of partnership with New Brunswick High School to develop and implement six-year Advanced Manufacturing/Mechatronics Program and provide multiple pathways for students to:
– Earn high school diploma and receive industry certification.
– Continue for two more years to earn associate degree.
– Continue at NJIT to earn BSET degree.

Extending the K-12 Initiatives Into Undergraduate Education.
– Accreditation and accountability.
Provided NJIT faculty, instructors and Ph.D. students with professional development on appropriate syllabi, and alignment of course objectives, learning, outcomes and assessment, with criteria specified by accreditation agencies, and process for continuous program improvement.

Adapted a K-12 working protocol for the creation, implementation and assessment of standards-based lesson plans to use for alignment of college-level learning outcomes with accreditation criteria.
– Evaluation of undergraduate research programs.

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