

The Long-term Impact of Including High School Students in an Engineering Research Experience for Teachers Program

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Ms. Marie Anne Aloia, Bayonne High School

Marie is an alternate route teacher with an educational background in math, physics, chemical engineering and computer science. As the first girl in her family to go to college, and maybe to prove the point, she earned two bachelor's degrees, one from Montclair State University by day, and 8 years later, one from New Jersey Institute of Technology, by night, while working full time by day at Exxon Research and Engineering. While a traditional female career, like teaching, was the last thing on her mind, she was drawn to educational outreach because she herself had received so little career advice. She eventually ran the educational outreach program at Exxon. After 25 years, 20 at Exxon and 5 in the high tech industry, an unexpected layoff came at a bad time, she was also newly widowed. Job offers that were once plentiful were nowhere to be found. The first, and only, offer to finally appear was to teach physical science at Bayonne High School, for a significant pay cut. A new adventure began. In the 14 years since then, she got to start up a research program, an engineering program, a science club, two FIRST Tech Challenge robotics teams, and brought in several new programs such as Technology Students Association, Young Science Achievers, and ACS Project SEED. She's been invited back do pharmaceutical engineering research with Research Experience for Teachers at NJIT every summer for the last 10 years now, with her Project SEED students. In 2008 one of her research students became a Science Talent Search Finalist. He also won best in category awards at the Intel International Science and Engineering Fair two years in a row. In 2010 she was named a Society for Science and the Public Teacher Fellow, and served on the Advisory Council for Intel ISEF since 2012. Marie currently teaches three levels of engineering courses, that she designed, and coaches students doing science research projects for competitions.

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Abstract

The Research Experience for Teachers program (RET) has been found to be effective in exposing teachers to research and engineering principles with the objective of bringing their experience and new knowledge back to their classrooms. For the last ten years, New Jersey Institute of Technology, a university in the northeast has hosted an RET program in pharmaceutical engineering, with up to fourteen high school mathematics and science teachers each year. Several of the teachers have participated for multiple years, serving as coaches for the new teachers. One teacher, who participated all ten years, began to bring two to four of her students each year each who were supported by a stipend from the American Chemical Society Project SEED Program. In later years, other teachers also brought students so that in a given summer six to eight high school students worked as partners in research teams with teachers, graduate students and faculty. The proposed paper tells the story of how their participation in our RET program made a difference for the students of the teacher who participated in the RET program for ten years, including choice of subsequent courses in high school and extra-curricular activities. There were between two to four students each year for 9 years for a total of 26 students. Almost all of them used their research to form competitive science fair projects working in the research and engineering classes at their high school established by the RET teacher as a result of participation in the RET program. Many of the students won awards and all of them went on to attend four year colleges majoring in STEM or STEM related fields. As the high school these students attended is in an urban area with a high-proportion of under-represented and economically-disadvantaged students of which only an average of 51% go on to attend a four year college after graduation (in any major not necessarily STEM) this is remarkable.

Introduction

There has been a great proliferation of REU (Research Experiences for Undergraduates) programs among many universities across the country¹⁻⁸. The increase in these programs is a result of federally funded programs, including Research Experiences for Undergraduates funded by NSF, McNair Achievement Programs funded by the U.S. Dept. of Education and internal funding by universities. Engaging undergraduates in research is seen as a way to motivate students to pursue graduate studies after completing their undergraduate programs, as well as developing research skills and communications skills and enhancing students' overall educational experience. Studies on the impact of these programs on REU students have been reported¹⁻⁸.

While such programs exist on a more limited basis for high school students, impact studies of these programs are scarce. The earliest program for supporting high school students was Project

SEED, established in 1968 by the American Chemical Society to help economically disadvantaged high school students expand their, education and career outlook⁹. By the summer of 2016, Project SEED had provided research opportunities for almost 400 students¹⁰. The program has provided opportunities for students to spend a summer conducting hands-on, meaningful research with a scientist in academic, industry, and government research laboratories. However, there appears to have been no formal reports of the impact(s) that Project SEED may have had on the student participants. There is also a lack of information on any preparation the students may have received for the research experience as well as follow-up on how the research experience influenced students' learning in and out of the classroom or their choices regarding college and career. Further, the participation and/or the influence of the students' teachers is unknown.

Collaborative research projects among classes of students that included the teachers have been reported¹¹⁻¹². These research projects focus on topics that are of concern or interest among the different groups of students. One such project involved 15 teachers from different New Jersey schools, each teacher selecting 6 to 10 students in one of their classes for each of two years to participate¹¹. The theme of the research projects was the environment. Examples of research projects included: correlating air pollution levels with weather conditions and wind direction; and concentrations of pollutants from automobile exhausts on nearby roadways in rush hour vs. non-rush hour. During the school year, students at each school collected air samples, and measured and analyzed trace concentration levels of specified pollutants. Each class shared their results with the other participating schools, and comparisons were made among locations. This collaborative project between New Jersey Institute of Technology (NJIT) and high schools in New Jersey not only provided a research experience for the students, the teachers also gained new knowledge and skills that enabled them to translate the research process into their classroom practice.

A collaborative project of this type was replicated on an international scale through the partnership of NJIT and the Curriculum Research & Development Group at the University of Hawaii-Honolulu¹². Teachers and students in 15 of the United States, Hungary, Japan, Russia, Indonesia, Thailand, and Singapore were linked through an international electronic communications network, as they collected, analyzed, and shared data on environmental topics over a selected period of time, such as weather patterns, acid rain, soil analysis, and similar topics. This network provided a geographical distribution of student research across time zones and the international time line.

Research Experiences for Teachers

The Research Experience for Teachers (RET) Programs at NJIT, funded by NSF, was designed to provide high school science, technology and engineering teachers with a summer-long professional development program that includes a real-world research experience to help develop their research skills and enhance their knowledge of science and engineering concepts¹³. Teachers worked side-by-side with university research faculty, graduate students, and undergraduate students (participating in a parallel Research Experience for Undergraduates, REU site program) in discovery-based, hands-on research projects.

Teachers were provided with the guidance to translate their research experience into classroom practice and develop lesson plans relevant to their area of research¹⁴. As part of the program teachers developed instructional modules they could use to integrate into their classroom teaching¹⁵. The project also focused on helping the teachers refine their instructional planning skills and providing them with an effective protocol for developing standards-based lesson plans. In turn, it was expected that teachers' research experience(s) and implementation of the instructional modules in their classrooms would thus impact upon their students' learning and motivation to pursue studies in STEM areas¹⁶.

The success of the RET program has been reflected, in part, by the number of teachers who continued to seek a place in the RET programs that followed each summer. One such teacher was a participant in the first RET program, and since then has been invited back each year to participate in the program; the only teacher to have been invited back for each of the ten years of the program to continue development of engineering curricula for her high school and serve as a mentor for other teachers in the program.

This teacher's continued participation in the RET program led her school administration to ask her to create and implement an engineering program for the district. In response to the request of her school administration, the teacher created a sequence of engineering courses for the district¹⁷. The program included a research course, which eventually evolved to include various extra curricula activities.

Research Experiences for High School Students

This particular teacher also brought students from her high school each summer to be part of the research experience. During the first summer that she brought students, the students worked on a small research project different than the one in which she was involved but the students' interest and motivation to return the next summer was exceptional. During the second summer when they returned the students worked with their teacher on her RET project.

In the early days of RET program the projects given to the teachers were not always well planned. During the second summer of the RET program the projects assigned to the teachers were still being defined, but since this particular teacher had two extra sets of hands, (in addition to the fact that the students were already somewhat familiar with the research process from the previous summer) she was given the most complicated project. The research project was a success, more than the faculty and post-doc mentors were expecting and the project was passed on to a doctoral student for further development after the summer program concluded.

Most of the students that worked with her in subsequent summers were in the research class she developed for the high school, both before and after their summer work. They attended the engineering classes as well. Thus, these students entered their summer research experience prepared, and were able to follow up with their research after the summer.

Bringing high school students into our RET program expanded the program to include another generation of researchers. The students learned to solve problems in collaboration with others, and how to analyze data and make decisions based on the data and their previous knowledge.

Summary of Student Successes

Over the ten years of the RET project, this teacher involved 24 of her high school students in at least one summer research experience. Many of the students continued to be involved in research projects after the summer to add to what they learned. Some students come back to the university library to access research journals for school papers and other projects such as science fairs and some have won medals. A few students presented their research at national meetings of professional organizations, such as the American Chemical Society or participated in additional summer research programs in preparation for college. Many of the students also participated in engineering competitions such as TSA-TEAMS¹⁸ or the Panasonic Creative Design Challenge¹⁹.

In most cases their summer work helped them to decide on their course of study in college. All of them have gone on to college, and most of them received full scholarships. All of these students are pursuing a course of study or a career in STEM fields including chemistry, physics, biology and engineering; some have pursued degrees in Pharmacy, Pre-Med, Nursing, Criminal Justice, Forensics, Mathematics, Architecture, and Science Journalism. Many of the students are attending state colleges in the North East, but a few have gone to big private colleges including NYU, Harvard, Dartmouth and Washington and Lee.

Some students returned to our university; some as engineering majors. One student participated in a Research Experience for Undergraduates (REU) in his first year of college, while most undergraduate students do not participate until after their junior (third) year. The post doc advisor working with this student was surprised to know that he was only a first year student because he worked more like a grad student. He's now an MD-PhD candidate at Tufts University.

These are extremely remarkable accomplishments considering the fact that the high school these students attended is in an urban area with a high-proportion of under-represented and economically-disadvantaged students of which only an average of 51% go on to attend a four year college after graduation (in any major not necessarily STEM).

The teacher kept records of where the students reported attending college, their intended major and whether they received scholarships. See Table I for a detailed summary of the known colleges that 21 of the students attended, their gender, year(s) attended, their majors and any known scholarships.

Follow-up

As these students participated in a university program for which they provided home mailing addresses and the teacher kept records of where the students reported attending college and additional contact information, a follow-up survey is being sent to these students to gather information about how valuable they felt the experience was, how participation in our RET programs influenced their college and careers decisions and what their plans for the future are.

Table I
Detailed Summary of College Attendance

Year(s) Attended	Gender	College Attending	Known Scholarship	Major/degree
2007	Male	NJIT		Biomedical engineering
2008	Female	Stevens/NYU	Full Scholarship	Biomedical engineering
2008-2009	Female	Dartmouth	Questbridge Scholar	Pre Med
2009	Male	Rutgers		Science Journalism
2009	Female	Rutgers	ACS Scholarship	Chemistry
2009	Female			Pharmacy
2010	Female	Felician College	Scholarship	Forensics
2010	Male	Rutgers		
2010-2011 2012 REU	Male	Rutgers Tufts University		Chemistry MD PhD
2011	Male	The College of NJ	ACS Scholarship	Chemistry
2011	Male	Rutgers		
2012	Male	Rutgers		Mechanical Engineering
2012	Male	Washington & Lee	Questbridge Scholar	Math/Computer Science
2013	Male	Rutgers		Nursing
2013	Male	Rutgers		Engineering
2013-2014	Male	NJIT		Biology/Pre Med
2014	Male	NJIT		Biology
2014-2015	Female	Rutgers		Neuroscience
2015	Female	Notre Dame		
2015-2016	Female	Still in High School		Graduating 2017
2016	Female	Still in High School		Graduating 2017

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