

**AC 2008-627: A STUDY ON THE EFFECTIVENESS OF AN INNOVATIVE
RESEARCH PROGRAM FOR URBAN HIGH SCHOOL STUDENTS**

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A Study on the Effectiveness of an Innovative Research Program for Urban High School Students

Abstract

In the United States certain ethnic groups are underrepresented in science, technology, engineering, and math (STEM) fields. National Science Foundation and Census Bureau data show that, while the population of Blacks and Hispanics in the United States is 12% and 13%, respectively, in STEM undergraduate programs these groups only account for 8.5% and 7.2% of the student population. This lack of minorities in STEM undergraduate programs also impacts the potential graduate student STEM population, where Blacks and Hispanics compose 5% and 4.8% of the populations. These numbers have increased slightly over the past decade, but are still significantly lower than where they could be. By making STEM fields more appealing and accessible to minority students, their representation in undergraduate programs should rise to more closely agree with that of the overall population. Further, this increase should positively affect the minority population in STEM graduate programs and professional careers. Considering the expected growth in STEM jobs over the coming years, an increase in STEM-educated minority professionals will be extremely beneficial to the country's international competitiveness.

To increase minority high school students' interest in STEM, the Polymer Envoys Program, an innovative outreach program, has been developed and is being piloted. This program features a two-year research internship where urban high school students are matched with a graduate student mentor, and participate in STEM research during their junior year, the summer between their junior and senior years, and their senior year. A study is being used to determine the effectiveness of this program. Issues considered include the initial selection of student participants, the experiences of student participants while in the program, the related academic choices students make while in high school, and the post-program choices students make regarding college and major.

Evaluations indicate that this program has had very positive results in its initial phase of implementation. While many students initially indicated minimal experience with research and technical communication, in one year all have made significant improvements. This change was self-reported on surveys, and observed in the oral and written communication assignments completed by the students. Additionally, positive changes were observed in students' academic and career aspirations through their experiences in the program. Students initially indicated interests in obtaining no higher than Master's degrees in a variety of fields, but now all have expressed a desire to earn doctorates in STEM disciplines. One student also started taking math and science classes at the local community college based on the encouragement of her graduate student mentor and her greater understanding of opportunities to better prepare for college. Another student's research data is included in a technical paper currently in preparation.

Further studies of the program will include tests to determine how effective recently implemented program content is in supporting the students. Additionally, since a key goal of the program is to encourage and prepare students for STEM degree programs, the number of

program alumni who matriculate into colleges and major in STEM fields will be tracked. As possible, the longer-term impact of the program will be studied to determine how many of the students eventually pursue graduate studies in STEM.

Introduction & Background

In the United States certain ethnic groups are underrepresented in science, technology, engineering, and math (STEM) fields. These groups include Blacks, Hispanics, and Native Americans. National Science Foundation¹ and Census Bureau² data show that, while the population of Blacks and Hispanics in the United States is 12% and 13%, respectively, in STEM undergraduate programs these groups only account for 8.5% and 7.2% of the student population. This lack of minorities in STEM undergraduate programs also impacts the potential graduate student STEM population, where Blacks and Hispanics compose 5% and 4.8% of the populations¹. These numbers have increased slightly over the past decade, but are still significantly lower than where they could be. By making STEM fields more appealing and accessible to minority students, their representation in undergraduate programs should rise to more closely agree with that of the overall population. Further, this increase should positively affect the minority population in STEM graduate programs and professional careers.

Since the number of jobs in these fields are growing at a rate much faster than the production of new degrees in these areas³, it is important to consider how these underrepresented groups can position themselves to fill such positions. Many of these jobs will require college-level degrees, therefore students often must have an interest and show promise in math and science while in primary and secondary school in order to allow themselves the opportunity to pursue college degrees in the STEM disciplines.

Many universities have developed programs that seek to encourage pre-college underrepresented minority students to pursue STEM degree and career opportunities. Unfortunately, little available research has been done on such programs. However, some similar programs have been developed for women students, also an underrepresented group in STEM, and for high school students of any background. Bell, Blair, Crawford, and Lederman⁴ have reported on the impact of an eight-week science apprenticeship program on high school sophomores and juniors. In this study the metrics for success were based on concepts advocated by the National Research Council in its National Science Education Standards⁵, which encouraged learning science within the context of real-world problems. This concept of learning by doing is the basis for many apprenticeship programs. However, in the study by Bell, et al., the students were found to have changed their ideas of science and scientific inquiry very little between the beginning and end of the program. The sole student who had a significant positive change in these areas was found to have done significant reflection on the project throughout the experience.

Another example of a high school program in the literature is by Murphy and Sullivan⁶. This program was specifically for entering eighth grade minority females. In this program team projects were used to demonstrate scientific concepts and interest the participants in STEM disciplines. The study found that the students' top three goals in the program shifted somewhat from the beginning of the program to the end. Gaining scientific knowledge and skills in

teamwork, leadership, and management were important at the beginning and the end. However, initially students included increased self-esteem as a top three goal, and at the end the ability to describe scientific findings became one of the top three goals. In addition to surveying the students, the parents of the students were surveyed. One key finding was that the families were introduced to the benefits and opportunities the scientific careers. Therefore, such programs not only affect the way participants think about science, but they also affect the impression of science in their family and community. As studies have shown, this greater interest in STEM by role models can have a tremendous impact on whether that student pursues such fields^{7,8}.

On this note, it is also very important to consider societal and attitudinal differences that affect a student's interest in pursuing a certain field. Signer, Beasley, and Bauer⁹ studied the interaction of ethnicity (White vs. Black), mathematics achievement level (compensatory vs. non-compensatory), community socioeconomic status (low vs. high), and gender on math self-concepts in high school students. Data indicated that the mathematics achievement level, socioeconomic status, and ethnicity three-way interaction had an impact on academic aspirations in math. Low-SES Black students in compensatory math classes and high-SES Black students in non-compensatory math classes were most likely to have an interest in taking advanced math classes. Math self-concept also showed a significant interaction between ethnicity and mathematics achievement level. White students in non-compensatory math classes and Black students in compensatory math classes were more likely to indicate that their math ability was the reason for their class placement. However, White students in compensatory classes and Black students in non-compensatory classes were more likely to attribute their placement to effort. Therefore, a difference appears to exist between different ethnic groups regarding interest in math classes and what influences placement. While some of this difference is cultural, much of it could be mitigated by exposing students to the interesting aspects of STEM disciplines and giving them encouragement to be successful in these fields. With proper mentoring, summer and academic year research programs for high school students can fill this need.

Along with interest and effort levels, one key issue that minority students in urban areas face as they begin to explore career opportunities is a sense of empowerment, or lack thereof. Many of the students considered in this study have been marginalized culturally and economically in society. McWhirter¹⁰ showed that in a study of Mexican-Americans and Euro-Americans, the Mexican-Americans and women were more likely to be concerned about ethnic and/or gender discrimination adversely affecting their careers. Mexican-Americans also expressed preventative attitudes, such as a feeling of not being smart enough, not being able to go to college, and not fitting in. Therefore, programs need to be developed to show the students that they are important and needed in STEM fields. Elmesky¹¹ reported on a program in which student researchers developed a movie to enhance current STEM curriculum. The study found that the student participants sought out appropriate resources and created a video that was unique to their background and interests. If such empowerment techniques are used in science apprenticeship programs, students will also feel more comfortable with the subject and their place in STEM.

Many recent reports by the government, policy organizations and educational researchers point to the need for STEM education reform. The seminal report, "Rising Above the Gathering Storm"¹², has been especially helpful in bringing the issue to STEM global competitiveness to

the attention of the nation. This report highlights the need for revised STEM curricula and improved teacher education on the pre-college level. As stated by the committee,

The US system of public education must lay the foundation for the developing of a workforce that is literate in mathematics and science, among other subjects. It is the creative intellectual energy of our workforce that will drive successful innovation and create jobs for all citizens.

Considering the prevalence of polymers in our society and the potential future that they promise, there is a tremendous opportunity to use polymers as a tool to excite students toward STEM.

Program Description

The Polymer Envoys Program (PEP) was developed through a partnership between the university and a local urban school district to address the lack of opportunities for high school students. The research component has been modeled after similar successful programs at local private high schools and informed by relevant literature. In PEP, students are identified during their sophomore year as having the potential to be successful in science and engineering. Due to their highly positive experiences in the program, high school participants have been excellent recruiters of their peers. Selected students are assigned to a graduate student mentor and do research with that mentor during their junior year, the summer between their junior and senior years, and their senior year. During the academic year the time commitment is five hours per week, while the students work full-time for six weeks over the summer.

PEP participants present formal oral or poster presentations on their research project at least three times per year, and attend various events sponsored by and/or relevant to the program. These events include monthly meetings during the academic year, weekly meetings during the summer, a welcome meeting for new students, and other social and professional development events. Additionally, regular program meetings with the students feature presentations by faculty and staff on polymer concepts, technical communication, and planning for college.

Students in PEP additionally develop demonstrations that can be shown to middle school students and younger high school students. These demonstrations illustrate general polymer science concepts, as well as describe the student's project. They additionally serve as long-term recruiting tools for PEP. PEP students are expected to do at least one demonstration each semester they are in the program. Such demonstrations serve as ways to empower students as advocated by Elmesky⁹.

While PEP is a means of directly impacting a select group of high school and middle school students, the organizers recognize that it is important for the program to touch a larger number of people. Parents and guardians of the participants are expected to attend an evening event in the spring that welcomes the incoming class of Polymer Envoys, provides facility tours, introduces them to faculty and graduate mentors, and allows time for the students and their families to ask questions. This event also includes a symposium presenting the work of current Polymer Envoys students, giving incoming students and their families the opportunity to learn from students already in the program. New programs are additionally in development for 7th-10th grad students that would allow them to meet with the PEP organizers and related faculty members to learn about general materials concepts and gain experience with basic science experiments. In this

way the program can reach out to a larger number (~75/year) of students at a younger age, and some of these students may later consider applying to participate in PEP.

In the school district, parallel activities have been developed for students and teachers so that a larger number of people may be positively affected by PEP and related initiatives. These parallel activities include support for teachers to be involved in the Program. The school district's central administration has responsibility for identifying the high schools that participate in PEP, and for matching program organizers at the university with teachers and administrators in the high schools for student recruitment and retention purposes.

Study Overview

This study seeks to determine the short- and long-term impacts of participating in college-level science and engineering research on urban high school students. The researchers hypothesize that such an experience will increase a student's confidence in her or his technical abilities, and increase the chance that the student will pursue a career in science or engineering. In order to accomplish this, the following questions are being addressed: (1) Are the high school selection and student selection processes appropriate to meet program goals? (2) How is a student's perception of and interest in science and engineering affected by the research experience? (3) How will the experience affect the student's perception of her or his technical abilities? (4) How will this program affect the number of urban students who go to college, and who intend to pursue science and engineering majors once there? An examination of question 4 has recently begun and data are currently unavailable, but data on questions 1-3 will be presented in this paper.

Participants

The total population for this study will consist of students who are participants in the Polymer Envoys Program. Since there are six to ten students selected to participate in this program each year, all students will be invited to participate in the study. Students are selected from three high schools within an urban public school district with approximately 56,000 students (81% minority) and a graduation rate of 55%. Current studies focus on the participants in this initial PEP site, while future studies will also include participants in PEP sites at other partner university/pre-college sites.

In PEP student selection, high school science teachers, mathematics teachers, and counselors at selected schools first identify talented sophomores who have the potential to be successful in science and engineering. These sophomores are given information about the program and encouraged to apply. In addition to general information about the student, the application requires an essay and a transcript. The high school representatives and school district representatives read all student applications to determine appropriateness before the applications are shared with the PEP selection committee at the corresponding university. The selection committee, which is composed of faculty and staff, then reviews all applications to determine which students will be invited for interviews. After interviewing the students, the selection committee makes a final decision to extend an offer or not to each student. Selected students are

expected to participate in the program during their junior year, the summer between their junior and senior year, and their senior year. Students are given a stipend for participation in PEP.

Instruments and Study Design

Surveys each semester ask students for academic and attitudinal information so that changes over time may be tracked using multiple-choice questions with Likert-like scales (1=strongly agree, 3=neutral, 5=strongly disagree). Some short answer questions also ask for the students' opinions on their aspirations, and expectations or feedback on research and program activities. This allows for the determination of effective and ineffective activities so that they may be modified as necessary to make all activities as effective as possible. Most students in PEP are minors; therefore student assent and parental consent are collected before the students participate in each aspect of the study.

PEP organizers developed the pre-research and end-of-term surveys used in the program. Previously developed survey instruments for similar programs with validity information were sought, but could not be found. Since some students may choose to not participate in the research on the program, surveys are number-coded in order to ensure that there is no confusion between surveys that will only be used for internal improvement and those that will be used for research. By coding the surveys with a number, each student's responses can be compared with her or his previous responses in order to measure progression relative to the questions posed. In this way program impact may be determined over a semester, one-year, and two-year period. Since these are untested survey instruments, validity will be determined once enough data have been collected.

This is a descriptive study to understand the impact of PEP on high school student participants. Therefore, descriptive statistics are used to evaluate the program impact. Considering the small population available for this study, the mean and range are the primary ways used to discuss the survey data. Once sufficient data exist, the Pearson r correlation coefficient may also be used to determine relationships between pairs of variables.

Limitations

While the researchers believe that this study will determine very useful information about way to encourage urban high school students to pursue degrees and careers in science and engineering, some limitations exist. First, related to the participants, students are identified based on previous interest in science and math, and desire to go to college. Therefore, the results should not be considered ways to encourage students who lack interest in these areas to consider them. However, future evaluations on recently initiated PEP demonstrations for younger students will provide information on activities that excite students. Teachers recently identified from the high schools involved are also active in developing polymer-related lessons for middle school and high school students. Therefore, these lessons will allow for a study on their effectiveness in exciting pre-college students. Another limitation is that the previous academic preparation of students is not considered in this study. Therefore, some students may encounter significant struggles and frustrations due to a lack of preparation for this type of project, and this might

impact the answers given. Tutors were recently introduced in the program to support students academically and in so doing minimize the impact this limitation.

A final limitation is that this study does not currently consider the mentoring techniques used by the graduate students with the high school students. Since some graduate students are better than others at mentoring and the relationship that a mentor-mentee dyad has will affect the experience of the high school student, the impact of mentoring will affect the results of this study. The researchers are working to minimize this effect by providing mentoring seminars and making expectations clear for the mentors. Future survey revisions will include questions specific to the mentoring process such that this impact may be assessed.

Study Results To Date

School district mathematics and science coordinators in the district's central administration initially chose the schools involved in PEP. The key criterion for this selection was proximity to the local college since high school students would need to go to campus regularly for meetings and research. While excellent students were identified at these administration-selected schools, school and teacher commitment to and interest in the program were lacking. Therefore, in the second year of program implementation, the school selection process was revised to allow all district high schools to submit proposals if they wished to participate in PEP. This process recently completed and was found to work very well because schools better understand their expectations and have committed to fulfill these expectations. Inversely, current schools that did not feel they could meet program expectations had an opportunity to opt-out of the program. Additionally, based on demographics in the new schools selected, it is expected that the high school student participants will become more diverse than what was achieved in the first classes of students.

In the first two years of PEP, 12 students were selected and started as sophomores (1), juniors (8), and seniors (3). Key selection factors include a student's grades and interest in math and science, level of maturity, and enthusiasm toward the program. In initial student evaluations, student participants considered themselves to be proactive in problem-solving (mean response of 1.5), and comfortable asking for help from peers and people in authority (response of 1.6). While students of all levels have been successful, it has been found that juniors are the ideal level for new students. This is because the high school has known the students and the students have demonstrated academic success for a year and a half before the students apply to PEP, and the program has two years to work with the students before they apply for college. Support available to students through PEP includes the graduate student mentor, the program coordinator, the faculty advisor, and tutors in math, science, and English. These individuals work together to academically and socially support students in their research projects and school courses as necessary.

The program has also learned the importance of explicitly stating the time commitment for student participants. While PEP expects students to be in the lab for 5 hours total each week, organizers have found that students often have to choose between participating in the program or in school sports or clubs. Therefore, by making this expectation and potential choice clear to students initially, the students who agree to participate are less likely to leave the program

compared to students in the initial class, for whom this matter was not stressed. Three of the original six students selected for PEP left the program early and another one took a semester away from the program, while only one of the six students in the second class has left the program to date. Since student matriculation into a partner higher education institution is a key goal of the program, the number of seniors who choose to attend these institutions is a measure of the quality of student selection in PEP. Two of the current three seniors in the program applied and have been admitted to the host university, leading the authors to believe that student selection has been successful in attracting the desired type of students.

Student evaluations indicate very positive results in its initial phase of PEP implementation. While many students initially indicated minimal experience with research and technical communication, in less than two years all have made significant improvements. This change was self-reported on surveys (responses of 3.6 initially, to 2.3 after one year in program), and observed in the oral and written communication assignments completed by the students. Additionally, students' academic and career aspirations have been affected through their experiences in the program. While most students initially expressed interest in becoming scientists and engineers and felt that they were capable of being in such fields (initial response of 1.9), through the program some became more interested in STEM careers (response of 1) and others became less interested (response of 2.8). While the program aims to excite students toward these fields, aiding a student in realizing that this is not her or his area of interest is equally important.

Regarding students' experiences and success in current math and science courses, through encouragement by PEP organizers and graduate student mentors, and presentations by undergraduate admissions representatives, some students have considered and started to take courses at the local community college. Additionally, as appropriate, some students have been invited to take classes at the university through the pre-college scholars program. While these are opportunities that were available to the students before participation in PEP, many students did not recognize the importance of taking advantage of such programs. Therefore, the program has played a key role in expanding students' horizons and helping them to recognize steps necessary to be competitive in the college applications process.

In the first year of the program, many of these changes were attributed to the students' experiences in the lab. However, starting in the second year of the program, regular meeting were modified to include content relevant to polymer science and engineering. Such concepts included a general overview of polymers, presentations on polymer chemistry and physics, and an overview of technical communications. One measure of the program's ability to affect students is through the questions students asked during regular program meetings. For example, students were able to connect what they were learning in their high school classes to polymer concepts. In this way they were better able to understand the real-life applications of introductory science concepts. Additionally, tutors were identified to academically support the high school students in their current classes. The quantitative impact of these new activities on students' experiences in PEP and in their classes is currently being evaluated.

The end-of-semester questionnaire also asked questions about the top factors that influenced a student's choice of college. While student responses varied, the issues that most students

indicated as factors were the cost of college and financial support available. Since these are students from a low socioeconomic status area, this concern over paying for college is not unreasonable. However, it also re-emphasizes the importance of making funds available to support students with financial need. PEP organizers are working to develop scholarships for program alumni who matriculate into the host university so that financial concerns are minimized for interested students.

In addition to students completing questionnaires, the graduate student mentors filled out end-of-semester questionnaires about their experiences with PEP. One positive response was that all felt that they made a positive difference in their high school student's life. However, some felt that their involvement took too much time away from their own research and studies. This was partially because the high school students come from schools that often lack lab resources, and this lack of academic experience in science sometimes slowed the project and caused the mentor to spend more time than expected with the high school student. Since some graduate students had limited previous mentoring experiences, they also expressed a desire for more guidance on what was expected of them. This was addressed through the aforementioned summer mentorship seminar geared at graduate students who were mentors to high school and undergraduate students. Mentors gave very positive feedback on this seminar series, as it created a mentor network, helped them think about issues that might arise before they arise, and allowed them to share any frustrations and suggestions with each other.

Conclusion & Future Work

In less than two full years of implementation, the Polymer Envoys Program has shown significant indications of success toward the goals of increasing pre-college minority students' interest in STEM careers. At the pilot site, surveys by student participants indicate continual progress in students' confidence in STEM and interest in pursuing graduate degrees in STEM disciplines. Students have also shown tremendous growth in their oral and written communication abilities, which are key skills necessary for STEM and other fields. These results all point to a highly successful and effective program, and its success has encouraged other faculty at the university to include similar programs in their funding proposals.

In the future, since a key goal of PEP is to encourage and prepare students for STEM degree programs, one very important future study will be to track the number of program alumni who matriculate into colleges and major in STEM fields. While students are encouraged to consider universities connected to PEP, the program supports them in applying to all institutions of interest. In order to prepare students for the college application and selection process, speakers from undergraduate admissions offices have been invited to speak with the students during regular meetings. As previously stated, financial aid has come up as a key factor for many students in deciding on a college. Therefore, the PEP organizers are working to develop scholarships that will be available to alumni of the program who choose to attend that university. Additionally, a list of major scholarships was given to all students so that they can pursue external funding options. As possible, longer-term impacts of the program will be studied to determine how many of the students eventually pursue graduate studies in STEM.

As previously mentioned, the current study focuses on the initial PEP site. However, two partner universities have recently started PEP sites with their local pre-college schools, and at least one additional site is in development. Activities and best practices are already being shared among sites so that all institutions can learn from each other and improve continuously. Future studies on PEP will investigate how similarities and differences among the program operations affect key student outcomes.

Finally, since PEP is resource and time intensive, as previously stated there are plans in development to grow the program without adding a significant time commitment to the faculty and graduate students who already do the majority of the work. One idea is to host a monthly Saturday morning series at which 7th-10th grade students would be exposed to polymer science and engineering concepts, and participate in hands-on activities. Since some students who applied to the PEP were turned down due to their already busy weekday afternoon schedules, offering activities on weekends would allow PEP organizers to interact with students who are academically-motivated but participate in significant extracurricular activities. Since the group would meet monthly as a cohort, a similar study could be used to determine the impact of this less time intensive program on students. Additionally, this group will likely show an initially broader range of interest in STEM compared to students in PEP. Therefore, model techniques to excite students toward these fields may be determined.

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