Access to Engineering:
An Evaluation of the Success of a Pre-Collegiate Program for African-American High School Students

Nancy Shields, H. Richard Grodsky, William P. Darby, and Joseph Pietroburgo
University of Missouri-St. Louis/Washington University
Joint Undergraduate Engineering Program
Benton Hall 228
8001 Natural Bridge Road
St. Louis, MO 63121

Abstract

This paper is an analysis of the success of a pre-collegiate program for African-American high school students. "Access to Engineering" was sponsored by The Boeing Company, in conjunction with the University of Missouri-St. Louis/Washington University Joint Undergraduate Engineering Program. It was a seven-week summer program designed to introduce 16 African-American rising seniors to the fields of mechanical, electrical, and civil engineering. The program included field trips, hands-on engineering labs, presentations by engineering faculty members, and computer activities of all kinds. Finally, students learned what it is like to work as an engineer by actually solving design problems that take more than just narrow technical considerations into account. Students experienced the team approach to problem solving that typifies both engineering education and the world in which engineers practice. Most of the students took an intermediate algebra course in the morning, and participated in the engineering activities in the afternoon.

In order to evaluate the program, several variables were measured at the beginning and the end of the program: knowledge of pre-college level algebra; academic "locus of control"; and attitudes toward the field of engineering. The attitudinal measure included items concerning commitment to the field of engineering, knowledge of the field of engineering and what engineers actually do, attitudes toward the profession of engineering, the student's belief that he or she is capable of becoming an engineer, and attitudes toward math, chemistry, and physics. The field trips, laboratories, and the design project were also evaluated by the students. The findings revealed a highly significant increase in mathematics scores, significantly greater knowledge of the field of engineering, and greater family support to study engineering over the seven-week program. There was also a less dramatic, but positive increase in commitment to study engineering. The engineering activities were well received by the students.

Background

Overall, undergraduate engineering enrollments have been declining, while at the same time the demand for engineers has been increasing. Many are concerned that America will not have a sufficient supply of scientists and engineers in the workforce for the 21st century.[1] Even though undergraduate engineering enrollments showed a 2.5 percent increase between 1996 and 1997 (the first increase since 1992), the constant decline in overall undergraduate engineering enrollments since 1993 portends a decline in engineering degrees at the end of the decade and in the year 2000.[2] The decline in engineering enrollments is consistent with decreasing undergraduate enrollments overall, resulting mainly from a decrease in the college-age cohort of the majority (Caucasian) population. There seems to be widespread agreement that we need to look to underrepresented groups if we are to remain competitive, much less maintain our current position of leadership in an increasingly global market.

By 1996, underrepresented minorities represented only 15 percent of the total undergraduate engineering enrollment.[3] Currently however, African Americans alone constitute nearly 30 percent of the college age population. On a positive note, the number of underrepresented minorities enrolled in engineering programs increased from 41,000 in 1990 to almost 54,000 in 1996. At least some of this increase is probably due to the implementation of programs designed to encourage African-Americans and other minorities to study engineering, some dating back to the early 1970s. By 1986, a directory was published, listing 138 year-round pre-college and university level minority engineering programs, and eight national organizations involved with minority engineering educational efforts.[4] Empirically based evaluations of such programs, however, have been far less numerous or accessible than overviews which focus merely on a particular program's goals, rationale, and mode of operation. Clearly, there is an obvious need for more systematic evaluations of such programs.

Description of the Joint Undergraduate Engineering Program

The Joint Undergraduate Engineering Program is a partnership between the University of Missouri-St. Louis and Washington University, established in 1993. A major goal of the program is to provide a high quality engineering education to students in the St. Louis area who are place-bound. Many of these students are women and minorities. The program offers degrees in mechanical, electrical, and civil engineering, and a minor in environmental engineering science. There are currently 314 students enrolled in the program, 16 percent are African-American and 17 percent are female. The Joint Program has co-sponsored a program called "Access to Engineering" for three summers. The McDonnell Douglas Foundation provided funding to the University of Missouri-St. Louis for the Access to Engineering Program in the summers of 1995 and 1996, and the Boeing Foundation continued to provide funding for the program in the summer of 1998.

Description of the 1998 Access to Engineering Program

The major goal of the program was to introduce rising high school seniors to the field of engineering and the challenges of an engineering career. Nearly all high school students take courses in mathematics and the natural sciences but very few have any exposure to engineering. Toward this end, the afternoon sessions were devoted to providing participants with both hands-on engineering activities and exposure to a variety of engineering disciplines and professionals.

There were three major elements of the introductory engineering experiences: field trips, engineering laboratories, and a final design project. The activities were organized to emphasize the role of mathematics and science in engineering, engineering in society, and the three engineering disciplines offered in the Joint Program consisting of civil, electrical, and mechanical engineering. As a result, participants were exposed to both the breadth of work and the kinds of challenges that engineers face as working professionals.

The first week consisted of sessions to demonstrate the use of mathematics and science in engineering, plus an overview of the fields of civil, electrical and mechanical engineering. The sessions on the role of mathematics and science in engineering attempted to answer the question, “Why do I have to study all of this math, chemistry and physics prior to taking engineering courses?” The sessions consisted of presenting problems which utilized mathematics and science knowledge at the high school level to solve problems emphasizing the use of fact finding, approximation, and orders of magnitude. The participants were divided into groups and asked to develop a solution to a given problem and present their findings. The final session involved professors in the Joint Program presenting an introduction to the various disciplines encompassing civil, electrical, and mechanical engineering.

The next five weeks consisted of field trips, engineering laboratory experiences and guest lectures. Table 1 provides a list of the field trips taken by order of engineering major and the discipline within that major.

Table 1. Field Trips

Field Trip	Major	Discipline
Lock and Dam 26	Civil	Flood Control and Barge Transportation
New Federal Building	Civil	Construction
Water Treatment Plant	Civil	Environmental
Museum of Transportation	Mechanical	Transportation
Boeing Prologue Room	Mechanical	Aerospace
AmerenUE	Electrical	Computer Control and Power Distribution
AT&T Long Distance Switching Center	Electrical	Communications
Science Center	General Science and Engineering	General Science and Engineering

Next, Table 2 presents a summary of the laboratories held at Washington University. In these sessions, the students were divided into groups and were typically required to learn basic construction techniques and to use the instruments in the laboratory.

Table 2. Engineering Laboratories

Laboratory	Major
Earthquake	Civil
Material Stress	Civil
Environmental	Civil
Electrical Measurement	Electrical
Simulation	Electrical (Computer)
Diesel Engines	Mechanical
Lego Construction	Mechanical
Combustion	Mechanical

The last part of the program involved a design project that required the students to develop a solution which satisfied the stated requirements of the problem, and make a presentation on the morning of the last day prior to a recognition reception. Two different problems were used, both involving the problems of providing access to disabled individuals. The students were divided into groups of four, with two groups working on the first problem and two groups working on the second problem. A panel of four judges with both academic and industry backgrounds were assembled to judge the presentations for two awards, best technical solution and best presentation.

The students worked on the design projects in a computer classroom at the University of Missouri-St. Louis. The initial sessions were intended to provide an adequate background so the students could complete their designs and presentations. Initially, the design project requirements were presented utilizing a professional engineer from the commercial electrical design industry. In addition to providing an overview of the project requirements, the presentation included how to establish design goals, recognize constraints, develop assumptions, satisfy requirements and codes for the disabled, work in a group, etc. The presenter also gave many examples of personal projects and experiences.

Next, the students were trained to use computers by another professional from a local computer company. The first session involved training on the use of the Internet to conduct research in order to find required information to complete their designs – an example was to determine the various code requirements for access, minimum life safety standards, fire protection standards, etc. This was followed by a session to train the students to use PowerPoint to prepare overhead slides for their group presentations. The students then developed their solutions and presentations over the next several sessions.

Participants

African-American students were recruited from public, private, and parochial schools in the St. Louis area, as part of a larger program funded by the National Science Foundation (Heartland Alliance for Minority Participation). Students could choose to enter a general science track (the Scholar's Option), or the engineering component (Access to Engineering). The Access to Engineering component was funded by the Boeing Foundation in St. Louis. To participate in the program, students were required to meet the UM-St. Louis admission standards. The long term goal of both programs was to prepare students to be ready to take College Algebra and Trigonometry at UM-St. Louis during their senior year of high school, and then take Calculus I during the first semester of their freshman year.

Sixteen students chose the Access to Engineering track. Of the 16, all were African-American; two were male and 14 were female; 13 were rising high school seniors, and three were first-time freshmen. Before the program began, all students took the UM-St. Louis math placement examination. Based on the results of the testing, four of the students placed into College Algebra, and therefore were allowed to take other electives for credit. The remaining 12 took a specially designed mathematics course, which was designed to prepare them for College Algebra and Trigonometry. Eight of the students were dually enrolled at UM-St. Louis during the 1998-1999 academic year. The mathematics and other courses were offered in the mornings, four days a week (Monday through Thursday).

Methods

To evaluate the effectiveness of the mathematics component of the program, students took the UM-St. Louis mathematics placement examination before the program began, and at the conclusion of the program. The placement examination is designed to determine whether or not a student is ready to take College Algebra and Trigonometry.

The evaluation of the engineering component of the project was designed to measure attitudinal change in several different areas, as well as to evaluate the specific activities that were offered. The attitudinal aspect of the evaluation was based on work by Besterfield-Sacre, et al.,[5] Hoit and Ohland,[6] and Courtner, et al.[7] Several subscales (and a few individual items) were generated to assess change in the students' attitudes toward various aspects of engineering. The students were asked to respond on a five-point scale from strongly agree to strongly disagree to the items below. All items and subscales were scored so that higher values represented more positive attitudes. The items were presented in a random order.

<u>Commitment</u>
- I am sure I want to be an engineer.
- I know what kind of engineering I am interested in.

<u>Enjoyment of Math and Science</u>
- Math is my favorite subject.
- Science is my favorite subject.

<u>Perception of the Engineering Profession</u>
- Engineering is a respected profession.
- Engineers help solve the world's problems.

<u>Knowledge of the Field of Engineering</u>
- I know a lot about what engineers do.

- Most engineers sit behind a desk all day working with numbers.
- I have a good idea of what the differences are between mechanical, electrical, and civil engineering.
- Engineers use a calculator more than they write.
- Writing and communication are important skills for engineers.
- Engineers spend a lot more time communicating with technical people than with non-technical people.
- Every engineering problem has a right answer and a lot of wrong ones.
- I believe I will need to use my imagination to solve important problems and be successful in the field of engineering.
- It is important for an engineer to be able to speak before a group.
- An engineer needs to take into account a lot of non-technical concerns -- such as fashions, economics, ethics, and politics -- in solving technical problems.

Financial Incentive
- Engineers are well paid.

Family Influences
- My parents want me to study engineering.

Confidence
- I think I have the ability to master calculus.
- I think I have the ability to master physics.
- I think I have the ability to master chemistry.
- I believe that I have the creativity it takes to become an engineer.
- I believe that I can learn the computer skills that are necessary to become an engineer.

Study Habits
- I think I can succeed in an engineering major by studying the same way I do now.

Teamwork
- I prefer to work alone rather than in a group (reverse scored).

Academic Locus of Control
Because the program also contained a purely academic component (the mathematics course in the morning), we were interested in determining whether or not students felt more in control of academic outcomes after participating in the program. To assess this potential effect, Trice's Academic Locus of Control Scale was administered at the beginning and at the end of the program.[8] The scale is designed to measure the extent to which individuals view their own academic outcomes as being determined by internal (personal) or external (environmental) factors.

Students were asked to answer "true" or "false" to the following questions. The scale was scored by assigning a point to every response that suggested an "internal" response. Accordingly, higher scores indicate higher internal academic locus of control.

1. College grades most often reflect the effort you put into classes.
2. I came to college because it was expected of me. (reverse scored)
3. I have largely determined my own career goals.
4. Some people have a knack for writing, while others will never write well no matter how hard they try. (reverse scored)
5. I have taken a course because it was an easy good grade at least once. (reverse scored)
6. Professors sometimes make an early impression of you and then no matter what you do, you cannot change that impression. (reverse scored)
7. There are some subjects in which I could never do well. (reverse scored)
8. Some students, such as student leaders and athletes, get free rides in college classes. (reverse scored)
9. I sometimes feel that there is nothing I can do to improve my situation. (reverse scored)
10. I never feel really hopeless--there is always something I can do to improve my situation.
11. I would never allow social activities to affect my studies.
12. There are many more important things for me than getting good grades. (reverse scored)
13. Studying every day is important.
14. For some courses it is not important to go to class. (reverse scored)
15. I consider myself highly motivated to achieve success in life.
16. I am a good writer.
17. Doing work on time is always important to me.
18. What I learn is more determined by college and course requirements than by what I want to learn. (reverse scored)
19. I have been known to spend a lot of time making decisions which others do not take seriously. (reverse scored)
20. I am easily distracted. (reverse scored)
21. I can be easily talked out of studying. (reverse scored)
22. I get depressed sometimes and then there is no way to accomplish what I know I should be doing. (reverse scored)
23. Things will probably go wrong for me sometime in the near future. (reverse scored)
24. I keep changing my mind about my career goals. (reverse scored)
25. I feel I will someday make a real contribution to the world if I work hard at it.
26. There has been at least one instance in school where social activity impaired my academic performance. (reverse scored)
27. I would like to graduate from college, but there are more important things in my life. (reverse scored)
28. I plan well and I stick to my plans.

Evaluation of Engineering Activities

The students were asked to evaluate the specific field trips, engineering labs, and other projects that they had participated in over the seven weeks of the program. The labs were rated on a five-point scale (from strongly disagree to strongly agree) on the following items:

1. The lab was challenging.
2. The lab helped me understand the field of engineering.
3. The lab was interesting.
4. The lab was well organized.
5. The lab was presented in a clear manner.
6. If given the opportunity, I would participate in the lab (or one like it) again.

The field trips were rated on the following items:

1. The field trip helped me understand the field of engineering.
2. The field trip was interesting.
3. The field trip was well organized.
4. The field trip was presented in a clear manner.
5. If given the opportunity, I would participate in the field trip (or one like it) again.

The design project was rated on the following items:

1. The project was challenging.
2. The project helped me understand the field of engineering.
3. The project was interesting.
4. I learned to work in a group.
5. I learned how to prepare a formal group presentation.
6. If given the opportunity, I would participate in the project (or one like it) again.
7. I learned a lot about using the Internet.
8. I learned a lot about using PowerPoint to prepare a slide presentation.

Findings

Mathematics Scores

Four of the students placed into College Algebra and Trigonometry before the program began. The remaining 12 students took a math course designed to get them ready for College Algebra and Trigonometry. The scores of these 12 students increased dramatically over the seven-week period, from a mean of 10.75 to a mean of 14.75. This was a highly significant increase ($p < .001$). Only two of the 12 students did not have a high enough score to place into Algebra and Trigonometry.

Changes in Attitudes (Table 3)

Given the very small sample size (14), it was extremely difficult to show statistically significant changes in attitudes over time. However, in spite of the small sample size, two of the subscales increased significantly, and one almost reached a significant level. The subscale that was influenced the most by the program was the “knowledge” subscale. The students did significantly increase their knowledge of the field of engineering over the seven-week program ($p = .03$). According to the students, their families also became significantly more supportive of their interest in engineering (p = .08). Finally, the students also became more committed to the field of engineering, with the mean changing from 2.71 to 2.96, but the increase was only significant at a .13 level, due to the small sample size.

Although none of the other items or subscales changed significantly over the seven-week program, with only two exceptions, all did change in a positive direction or at least remained the same. For example, academic locus of control went from a mean of 17.85 to a mean of 18.62. Ironically, one of the items that changed in a negative direction was the one concerning working in a group. The mean on that item changed from 3.14 to 2.93. The other item that changed in a negative direction was the one concerning the financial rewards of the engineering profession, although the change was very small.

Table 3. Changes in Attitudes toward Engineering and Academic Locus of Control over the Seven-Week Program

		Mean	N	Standard Deviation	t	p
Commitment	Time 1	2.71	14	1.31	1.61	.131
	Time 2	2.96		1.31		
Enjoyment	Time 1	3.11	14	1.02	.12	.905
	Time 2	3.14		.97		
Perception	Time 1	4.18	14	.82	.69	.500
	Time 2	4.32		.67		
Knowledge	Time 1	3.38	14	.23	2.37	.034
	Time 2	3.60		.37		
Family	Time 1	2.07	14	1.14	1.83	.082
	Time 2	2.71		1.14		
Financial	Time 1	4.21	14	.70	-.43	.671
	Time 2	4.14		.53		
Study	Time 1	3.07	14	1.33	.00	1.000
	Time 2	3.07		1.33		
Teamwork	Time 1	3.14	14	.86	-.76	.459
	Time 2	2.93		1.21		
Academic locus of control:	Time 1	17.85	13	1.99	.92	.374
	Time 2	18.62		3.15		

Evaluations of Field Trips (Table 4)

Evaluations of the field trips were quite positive. A mean and standard deviation was calculated over the five items for each field trip. Four of the eight field trips had a mean rating of 4 or higher, in the following order: AmerenUE, the New Federal Building, Boeing, and the St. Louis Science Center. There was little variation in ratings. Three of the remaining four trips were rated at 3 or higher: Alton Lock and Dam 26, the Water Treatment Plant, and the Museum of Transportation. Only the AT&T Long Distance Switching Center rated below a 3 (mean = 2.81), and it had the highest standard deviation (1.20).

Table 4. Field Trips

Field Trip	Mean	Standard Deviation	N
AmerenUE	4.62	.62	13
New Federal Building	4.27	.69	12
Boeing	4.17	.47	13
Science Center	4.01	.98	14
Alton Lock & Dam	3.73	.96	14
Water Treatment Plant	3.37	1.20	14
Museum of Transportation	3.10	1.07	14
AT&T Long Distance	2.81	1.20	14

Evaluations of Labs (Table 5)

The labs were consistently and highly rated by the students, and agreement of ratings was high. The means ranged from 3.99 to 3.43, and the range in standard deviations were from .67 to .94. The Lego Construction Lab, the Earthquake/Material Stress Lab, and the Simulation Lab were received most favorably, and in that order. The Environmental Lab, the Combustion Lab, and the Diesel Engine Labs received intermediate ratings, and the Electrical Measurement Lab received the lowest rating.

Table 5. Labs

Lab	Mean	Standard Deviation	N
Lego construction	3.99	.67	14
Earthquake/Material stress	3.99	.84	13
Simulation	3.92	.60	13
Environmental	3.67	.80	14
Combustion	3.57	.51	14
Diesel engines	3.51	.76	14
Electrical measurement	3.43	.94	14

The Design Project (Table 6)

The final design project might have been the most challenging aspect of the program for the students, but it was very well received. Not one of the nine evaluative dimensions received a rating of less that 4, and the overall rating was 4.29. The projects were rated the highest in how they helped students understand the field of engineering, and how they helped students learn how to use the Internet. The design project was rated the lowest in terms of helping students learn how to make group presentations.

Table 6. Evaluation of the Design Project

Criterion	Mean	Standard Deviation	N
Overall	4.29	.66	14
Challenging	4.21	1.05	14
Understanding engineering	4.50	.76	14
Interesting	4.21	.80	14
Teamwork	4.29	.91	14
Group presentation	4.07	1.00	14
Would participate again	4.29	.73	14
Internet	4.50	.76	14
PowerPoint	4.29	.94	14

Discussion

Throughout history, the profession has struggled with the challenge of recruiting talented high school students into engineering. There are several contributing factors, including a general unfamiliarity with the field on the part of high school counselors and teachers, lack of an introduction to the field in typical high school curricula, and a generally confused notion about the profession and uncertainty of its contributions to the good of society among the public.

While employment forecasts show a promising picture of demand and career rewards for engineers into the 21st Century, presenting engineering as an attractive career to women and underrepresented minorities is one of our greatest challenges. This was the purpose of this program and of numerous comparable programs. Our ability to evaluate, according to various criteria, the outcomes of this program and to determine the degree of success met represents one of the major contributions of our work to the successful accomplishment of the goal common to our program and to numerous others.

It was, of course, difficult to demonstrate statistical differences using a group of 14 students. Nonetheless, over the course of the program, our results showed that students reported an increased knowledge of the field (achieved significance, 0.03). This was to be expected, of course. The students also reported an increased commitment to the field of engineering (achieved significance, 0.13), which was encouraging. Finally, students reported an increase in support from their families to pursue engineering (achieved significance, 0.08). This result does point out the important influence of families on their sons and daughters choice of careers. In our case, even as students learned the realities of the rigor and demands associated with an engineering education, their families' support and encouragement grew. The challenges of an engineering education, along with the occasional disappointment and discouragement of students during the process --- especially during the summer, a time generally associated with vacation and the absence of academic challenges for high school students --- may well have resulted in a perceived need by the families to be especially reinforcing of their sons and daughters resolve. This result suggests the importance of involving family members in programs and clarifying for all concerned, both students and their families, that the program is a serious academic undertaking with demands and expectations that may well exceed those that students experience during their normal school year.

Our ability to introduce students to the "hands-on" aspects of engineering through laboratory exercises was highly rated by the students. This result was expected, since many students begin to think about following an engineering career as the result of "tinkering" and may actually be "put off" when faced with the mathematical and scientific foundation of engineering practice. The early focus on the more theoretical foundations without reinforcement of the practical applications may be difficult for new engineering students, especially those who expected engineering to be a "hands-on" education and career.

We were especially encouraged by the students' reactions to the design project. While it was clearly one of the most challenging components of the program, it was also one of the best received. It was rated as the most effective mechanism for helping students understand the field of engineering. The students' ability to cope effectively with "open-ended" design problems for, perhaps, the first time in their lives was very promising, as was their interest and success in going beyond the merely technical problems and solutions most associate with engineering.

The increase in mathematics proficiency over the course of the program was excellent. Originally, four of the 14 students placed at the level of College Algebra and Trigonometry. The remaining 12 students took a mathematics course designed to prepare them for College Algebra and Trigonometry. The scores of these 12 students increased dramatically over the seven-week period, from a mean of 10.75 to a mean of 14.75. This was a highly significant increase ($p < .001$). Only two of the 12 students did not have a high enough score to place into College Algebra and Trigonometry at the end of the seven-week period.

We believe our evaluation of the results of this program have demonstrated the contributions programs such as this can make in awakening and reinforcing students' interest in engineering, and preparing them for a rigorous mathematics curriculum. Moreover, continued systematic evaluations of programs such as this will lead to continued improvement in the effectiveness and clearer models for new programs to be developed.

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Biographical Information

NANCY SHIELDS is Associate Professor of Sociology and Associate Dean of the UM-St. Louis/Washington University Joint Undergraduate Engineering Program. She has published numerous articles on student issues, and is currently conducting a study on place-bound students.

H. RICHARD GRODSKY is Associate Professor and Assistant Dean and Registrar in the School of Engineering and Applied Science at Washington University in St. Louis. He has been the director of three summer programs for minority and women high school students, and was formerly the electrical engineering advisor for the UM-St. Louis/Washington University Joint Undergraduate Engineering Program.

WILLIAM P. DARBY is Dean of the UM-St. Louis/Washington University Joint Undergraduate Engineering Program. He is the author of numerous publications in areas such as environmental risk analysis, and the use of quantitative methods, management techniques, and economic analysis for developing and responding to environmental regulations.

JOSEPH PIETROBURGO is the technical and statistical information specialist for the University of Missouri-St. Louis/Washington University Joint Undergraduate Engineering Program. Currently, he is developing a departmental information system that combines statistical and geographical analysis applications with the University’s student information system and emerging on-line data collection techniques.