A Pre-Engineering Program for the Under-Represented, Low-Income and/or First Generation College Students to Pursue Higher Education

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Abstract

This paper summarizes the findings of a twenty year old pre-engineering program that is aimed at improving both the recruitment and retention of under-represented students pursuing careers in Science, Technology, Engineering and Mathematics (STEM). The Wright Science Technology and Engineering Preparatory Program (STEPP) was initiated in 1988 for under-represented, low-income, first-generation college students interested in pursuing higher education. The effectiveness of the program over time is measured from the survey responses from students, average high school grade point average, retention rates of students returning from previous year, student enrollment in colleges, and percentage of students committed to STEM disciplines. This program serves as a model and a STEM approach valuable in preparing students for higher education.

Introduction

Ethnic minorities, especially African Americans, remain under-represented in a number of occupations, including those which are identified as high-technology areas. Engineering is one such area where African Americans and other minorities (defined here as Hispanics and Native Americans) have been traditionally under-represented [1]. In the United States, only 12.6% of all the first professional degrees awarded in 2001 are to under-represented minorities [2]. Also, 15.7% of the bachelor degrees awarded in science and engineering are to under-represented minorities [2]. In addition, the dropout rates for students from under-represented minorities in Science, Technology, Engineering and Mathematics (STEM) fields are substantially higher than other groups [3-9]. This demonstrates a need for greater efforts to train students in STEM fields.

Many colleges, such as the University of Maryland Baltimore County [10], University of Akron [11], Bowling Green State University [12] and others now offer some form of a pre-engineering or math/science program to promote the pursuit of undergraduate STEM education among under-represented groups. The primary goal of such programs is to increase the enrollment and retention of students from under-represented minorities that include African American, Hispanics, Native American and possibly Asian-Pacific. Other note-worthy goals of such projects include: (1) reinforce the self-confidence of under-represented students, (2) enhance students' problem solving skills through hands-on learning approach, (3) increase awareness of the student to pursue a career in STEM disciplines, and (4) provide diagnostic testing in mathematics and find the focus areas that require additional efforts prior to enrollment in college.

The College of Engineering and Computer Science (CECS) at Wright State University (WSU) is one such college that has identified this challenge early in time, and has initiated the Wright Science Technology and Engineering Preparatory Program (STEPP) for under-represented groups in 1988. The Wright STEPP provides inner-city students from Dayton Public Schools (DPS) a summer academic enrichment as a preparation to college. The primary goals of Wright STEPP are to: (1) demonstrate to students, the importance of graduating from STEM disciplines; (2) enhance the students' math skills as a preparation to college; (3) increase minority student enrollment in STEM programs; and (4) increase the retention rates. Additional goals of the projects are to: (a) reinforce students' self-confidence in STEM disciplines; (b) enhance students' problem solving skills; and (c) provide diagnostic testing in mathematics to determine students' respective weak areas before they enroll in college.

The participants in Wright STEPP program are under-represented students in the 7th through 10th grade from Dayton Public Schools (DPS). Every year, forty students from the 7th grade are admitted into the program, with a minor replacement in higher grades. Overall, 160 students (40 from each grade 7th - 10th) attend this four-week program that operates on WSU campus. With rewards being crucial for enhancing the intrinsic gratification and motivation for students [13], students upon successful completion of the four-year summer program are awarded a full-tuition scholarship to attend WSU and pursue a bachelor's degree of their choice.

Program Overview

The criteria for the admission into the program is: (i) students must attend DPS, (ii) students must have demonstrated interest in college prep math/science curriculum, (iii) the family must meet federal poverty income guidelines and/or meet the first-generation college requirement (neither parent has a four year baccalaureate degree), and (iv) students must have a 3.0 minimum grade point average (GPA). There is no cost associated for the qualified students to participate in Wright STEPP. WSU and corporate sponsors pays student expenses

for: (a) transportation, (b) meals, (c) field trips and cultural events, (d) classes, (e) course material, and (f) tuition scholarships. Instruction is provided by the scientists and engineers from Wright Patterson Air Force Base (WPAFB), and faculty from WSU.

The key elements in Wright STEPP program curriculum are (a) peer competence, (b) academic performance, (c) hands-on experience, (d) role models, (e) field-trips, and (f) financial incentives.

Peer Competence

Wright STEPP is designed to help hard working students who would not be able to pursue college education without monetary assistance. Due to a significant number of students meeting this criteria, admission is limited to those who perform well in their middle and high school. Students are nominated for this program by their middle and high school math/science teachers based on their academic potential for achievement i.e. current math/science grades, overall GPA, attendance, and no major disciplinary actions on record. During recruitment, students along with their parents or guardians attend a career-focused meeting at WSU, complete an application (which requires a 200 word essay) and attend an interview for acceptance into the program. Through this process, students earn their way into the program with hard work and perseverance.

Academic Performance

Admission to this program is based on student performance in middle and high school. Though students initially enter the program based on their prior performance, they are still required to maintain a minimum 3.0 GPA in order to continue. Failure to comply with the GPA results in the student being removed from the program. To demonstrate the importance of the student's academic performance, when ever the GPA of the student falls below 3.0, his/her place in the program is replaced by another student based on the high school teachers' recommendation. This criterion is used to encourage students to work hard while in middle and high school and maintain a minimum 3.0 GPA.

Hands-on Experience

Majority of the projects in Wright STEPP are designed focusing on STEM concepts through hands-on experience as supported by the National Science Board [14], and the National Council of Teachers of Mathematics [15-18]. This method provides students an opportunity to learn by doing thus enhancing their critical thinking [19]. This type of experience not only enables the students to learn better, but also increases their ability to move towards the successful completion of the job.

Role Models

Many incoming minority students in higher education lack the level of motivation and confidence necessary due to inadequate social support and role models. The motivation required is provided in Wright STEPP by role models through guest lectures and presentations. These personnel include scientists and engineers from WPAFB, local industry and WSU. They emphasize that success is achieved through competence and perseverance to work, but not through ethnic group status alone. These sessions are geared towards increasing the self-efficacy of students.

Financial Incentives

With rewards being crucial for enhancing the intrinsic gratification and motivation for students [13], participating students upon successful completion of the four-year summer program are awarded a full-tuition scholarship to attend WSU and pursue a bachelor's degree of their choice.

Program Curriculum

Wright STEPP consists of a four week summer component and a series of career workshops and tutorial programs throughout the academic year. For four weeks during the summer, pre-engineering students take a full schedule of academic classes, which include mathematics, physics, biology, chemistry, information technology and other engineering disciplines. Figure 1 shows the typical curriculum of Wright STEPP with respective focus areas. Through contact with successful engineers and scientists from WSU, WPAFB, and local industries, Wright

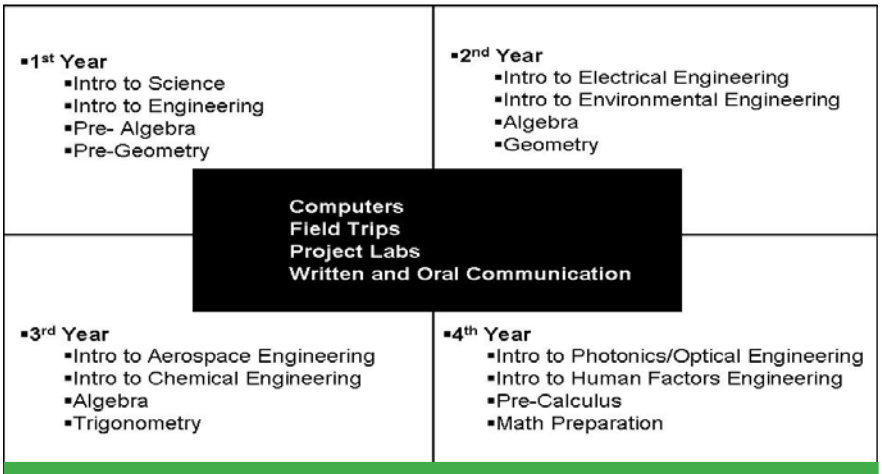

Figure (1): Wright STEPP Curriculum

	8:30 - 9:00	9:05 – 9:55	10:00 10:50	11:00 12:15	12:25 – 2:10
Monday	Administrative	Math Placement Prep	Pre-Calculus	L U N C H	Science
Tuesday	Administrative	Math Placement Prep	Pre-Calculus		Computers
Wednesday	Administrative	Math Placement Prep	Pre-Calculus		Project Lab
Thursday	Field Trip				Written & Oral Communication
Friday	Administrative	Math Placement Prep	Pre-Calculus		Hands-on science experience

Table 1: Weekly Schedule for Wright STEPP (10th grade)

STEPP students receive a first-hand opportunity and head start in higher education through a hands-on technology-based environment. Students learn not only math and science, but also written and oral communication skills, problem solving and study skills, and gain career opportunity awareness.

A typical weekly schedule of the Wright STEPP program is shown in Table 1. Students arrive at the university campus at 8:30 am, and gather in an auditorium between 8:30 – 9:00 am to discuss their daily activities, and attend a presentation delivered by the Wright STEPP alumni. Students attend classes and workshop sessions from 9:00 am - 2:10 pm with a lunch break of 75 minutes. Every Thursday during the four weeks of the program, students also visit a local industry to get an exposure to what an engineer/scientist does in his/her daily life, and understand the collaborative efforts involved behind making Wright STEPP successful.

Project Lab

Keeping the students interested and enthusiastic about STEM areas is becoming challenging in classrooms. To promote interest and motivation among the students, the instructional approach was restructured from teaching theory and manipulation of numbers to a pedagogy that was demonstrative and a curriculum that engages students in inquiry-based activities. A typical schedule and syllabus of the project lab for 10th grade students is shown in Table 2. The objective of this project lab is to design and launch a Temperature Satellite (Temp-Sat) to perform a parametric study on the temperature profiles in the atmosphere [20].

Week – 1	Learn about current, voltage, and resistance Learn about series and parallel circuits Discuss the importance, advantages and challenges of Integrated Circuits (IC) Discuss the operation of a Temperature Satellite
Week – 2	Study electrical diagrams and symbolic representation of electrical components Learn about printed circuit boards (PCB) and soldering Build the Temperature Satellite using PCB and ICs
Week – 3	Learn data analysis using spread sheets Learn about non-linear electrical components such as thermistors Calibrate the Temperature Satellite
Week – 4	Launch Temperature Satellites using helium balloons and perform parametric study on temperature Feedback session

Table 2: 10th Grade Project Lab Outline and Schedule

Workshop - A	Scholarship, Financial Aid, Housing, and Success in College
Workshop - B	Summer Jobs, Internships, and Cooperative Job Experience, and Undergraduate Research Opportunities
Workshop - C	Cover Letter, Resume Writing, and Interviewing
Workshop - D	College Placement Testing, College Orientation, and Retention Skills
Workshop - E	Meeting with Wright STEPP Alumni, College Experience and Life after College, Meet the Dean of College of Engineering and Computer Science

Table 3: Schedule of Workshops

The key components of this project are to (a) educate students in digital communication; (b) provide a hands-on cooperative learning and training experience in building an integrated circuit; (c) allow students build their own Temp-Sat module and collect temperature data from the atmosphere; and (d) teach students about data analysis using spreadsheets. The fundamental knowledge that students gained through this project built self-confidence, kept them enthusiastic about STEM, and enhanced their problem solving skills.

In addition to this project, students also worked on projects such as designing bridges, building household circuits, formulating a market plan for an engineering product, building motors using a Van de Graff generators etc. These projects are based on the primary premise that students can be challenged in the fundamental concepts of mathematical and physical sciences. By using a hands-on approach to learning, students are reinforced in the concepts of fundamental science.

Academic Year Component /Post-Wright STEPP

Upon successful graduation from Wright STEPP and while in 12th grade, students attend a series of workshops that are geared towards educating them about opportunities available while in college, life in college, and meeting key people from the local industry. Table 3 shows an outline of these workshops that occur during the academic year.

Also, prior to starting college education, Wright STEPP students also participate in a one week math tutoring program to enrich their math skills and get a jump-start to college. This program provides students with 20 hours of math instruction and reviews the math skills required during the first year of college. Through participation in this program, students get an opportunity to meet upper level and other freshman students, familiarize themselves with the campus, and overall get a jump-start on college life before the academic year starts. At the end of program, students are given a choice to retake the Math Placement Level (MPL) test to improve their scores and register in a higher-level math course accordingly.

Table 4 shows the typical schedule of the math tutoring program. Since social dynamics

Sunday
12:00 – 04:00 p.m. – Check in at dormitory for room assignment
05:00 – 06:00 p.m. – Get acquainted and "The Week Ahead"

Monday – Thursday
09:00 – 09:30 – Registration
09:30 – 12:00 – Mathematics
12:00 – 01:30 – Lunch Break
01:30 – 03:30 – Mathematics
04:00 – ? – Cookout (Monday only)
03:30 – 05:00 – Optional Activity (Tues, Wed, Thur)
06:30 – 09:00 – Optional Activity (Tues, Wed, Thur)

Friday
09:30 – 11:30 – Mathematics
11:30 – 12:30 – Lunch Break
12:30 – 05:00 – Math Placement Level Testing/Course Changes

Table 4: Schedule of Math Tutoring Program

are as important as classroom education, this program starts with a social gathering on Sunday evening where students are informally introduced to fellow classmates as well as upperclass students. This is later followed by an icebreaker to increase student rapport and break the typical barriers in meeting new people. The following four days, students attend math tutoring sessions from 9:30 am - 3:30 pm, and participate in social activities during the evening.

Improvement in student perceptions and their abilities were tracked in the program using surveys and test scores. A survey to understand student perceptions and their abilities as shown in Appendix-A and Appendix-B was conducted at the beginning and end of the program. Table 5 and Table 6 shows the results obtained from participating students in 2006. Based on this data, it is evident that the math tutoring program has helped to increase the self-appraisal and preparedness of students for an engineering program. This data also indicates that students now have a better understanding of math concepts, and as a result they were able to improve their MPL scores. In addition to improving math skills, the tutoring program had also provided students a platform to make new friends, form study groups, get familiar to campus, and overall have a jump-start to college.

Inherently, 97% of students stated that they had fun during the program. At end of the math tutoring program, students were given the choice to retake the MPL test and subsequently register for a higher-level math course if they improved their MPL score. It can be observed from Table 7 that the math tutoring program has had a significant impact with at least a minimum of 60% of students improving their MPL scores each year. This resulted in students starting their math course sequence at a higher level than they initially signed up for. Every year, approximately 20% of students had no improvement in their test score, but these students benefited in several ways such as reinforcing their math skills, making new friends, and getting a jump-start to college. On the other hand, approximately 10% of students had a decline in their test scores, and reasons behind which are not deduced currently.

Results and Implications

Wright STEPP has profoundly increased access and retention of under-represented, financially disadvantaged students pursuing STEM careers. Students have accepted the STEM learning experience with positive attitudes. Through subjective observations and

Question #	Pre-Survey Avg	Post-Survey Avg
1	3.47	4.05
2a	4.02	4.19
2b	3.67	3.85
2c	3.91	4.13
2d	3.70	3.98
2e	4.23	4.43
2f	3.78	4.05
2g	3.83	4.16
2h	3.89	3.96
2-self	3.88	4.09
3a	3.84	4.01
3b*	3.30	3.29
3c	3.64	3.84
3d*	3.12	2.93

* - Reverse scored, with low being the best.

Table 5: Pre and Post Survey Response comparisons from 2006

Survey Item	Response (1-Low, 5-High)
I have a better understanding of math concepts	4.15
Helped me to develop my problem solving and analytical skills	4.03
Interest in the evening activities offered	3.70
Number of evening activities I participated during the week	2.60
Extent to which professors were helpful in the math sessions	4.51
Extent to which student leaders were helpful in the math sessions	4.55
My overall evaluation of the math component	4.50
I would recommend this program to future incoming freshman students	4.73
I had fun	97.26%
Program met my expectations	94.59%

Table 6: Math Tutoring Program Survey Response in 2006

Year	Improved (%)	No change (%)	Decreased (%)
2000	60.52	26.31	13.15
2001	76.92	11.53	11.53
2002	68.91	16.21	14.86
2003	72.58	25.8	1.61
2005	64.61	26.15	9.23
2006	68.57	22.85	8.57
Average	**68.68**	**21.47**	**9.82**

Table 7: Trend of MPL Scores

judgments, it was found that the Wright STEPP had an effect on: (a) improving the study skills and habits of students; (b) improving teamwork, cooperative learning, positive competition, peer support; (c) creating a learning environment and a community committed to striving for excellence rather than settling for remediation; and (d) retention towards graduation.

Table 8 shows the retention rates of Wright STEPP graduates since its inception in 1988. From approximately 600 students that have graduated from Wright STEPP, 303 students have enrolled in WSU to pursue a bachelor's degree. Through timely modifications to the program curriculum, the average student retention rate has increased to 73%. Of the 113 students that have graduated from WSU by 2003, fifty two students (47%) have majored in STEM disciplines, with many others in progress.

Table 10 shows a comparison of retention rates between Wright STEPP graduates, College of Engineering and Computer Science, and Wright State University. It is evident from these comparisons that Wright STEPP students has a higher retention rate of 59.7%, over the CECS (23.63%) and the university (44.69%) clearly demonstrating its profound contributions in increasing retention rates. Also, the average ratio between number of female and male students in this study is 2.5. This shows that Wright STEPP also serves as a good model to recruit female students into STEM programs.

The impact of Wright STEPP on our nation's engineering and computer science workforce is significantly profound as it: (a) benefits underrepresented minorities by increasing recruitment and retention in STEM fields through quality intervention services, (b) demonstrates the importance of teaming to succeed in STEM fields, (c) prepares minorities for careers in STEM disciplines by valuing diversity, (d) enhances student communication skills and peer competence, (e) enhances the critical thinking process, and (f) enhances the partnership between government, higher education, local corporate industries and public high schools. Also, results obtained from the Wright STEPP added to our knowledge base, the effectiveness of interventions aimed at increasing minority representation in STEM disciplines. It is our hope that, implementation of such pre-college program will improve the learning opportunities and encourage the success of all students in the STEM curricula.

Year	Attended WSU	Graduated from WSU	In Progress	Retention (%)
1994	19	8	0	43
1995	19	6	0	32
1996	15	7	0	47
1997	21	9	0	43
1998	25	18	1	76
1999	17	10	3	77
2000	25	18	1	76
2001	22	17	0	78
2002	27	9	8	63
2003	21	11	2	62
2004	28	0	28	-
2005	18	0	18	-
2006	25	0	25	-
2007	21	0	21	-
Total	**303**	**113**	**107**	**73**

Table 8: Retention Rates of Wright STEPP Graduates

Year	Attended WSU	Graduated from WSU	STEM Major	% STEM Majors
1994	19	8	3	38
1995	19	6	4	67
1996	15	7	2	29
1997	21	9	2	23
1998	25	18	11	62
1999	17	10	3	30
2000	25	18	9	50
2001	22	17	9	53
2002	27	9	4	45
2003	21	11	5	46
Total	**211**	**113**	**52**	**47**

Table 9: STEM Majors from Wright STEPP Graduates

Year	Wright STEPP	CECS	WSU
1994	43	21.6	45.9
1995	32	23.1	39.0
1996	47	23.6	37.0
1997	43	26.4	48.2
1998	76	22.4	48.6
1999	77	21.4	44.1
2000	76	22.5	44.7
2001	78	28.0	50.0
2002	63	-	-
2003	62	-	-
Average	**59.7%**	**23.63%**	**44.69%**

Table 10: Comparison of Retention Rates between Wright STEPP Graduates, College and the University

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Appendix A

Pre-survey of Student Perceptions

Name: _____ **Current MPL Level:** _____

Use the Likert scale of (1-Low, 5-High for all the questions below)

1. How well prepared for the engineering undergraduate program do you feel you were as a result of your High School Math courses?

1 (Low) *2* *3* *4* *5 (High)*

2. On a scale of 1 to 5, compared to other college-bound students in your high school's math and science courses, rate yourself on each of the following traits:

1 (Low) *2* *3* *4* *5 (High)*

a. _____ Ability to set and reach goals
b. _____ Leadership abilities
c. _____ Competitiveness
d. _____ Communication skills
e. _____ Ability to work cooperatively
f. _____ Mathematical abilities
g. _____ Self-confidence (social)
h. _____ Self-confidence (intellectual)

3. On a scale of 1 to 5, please indicate the extent of your agreement with the following statements:

1 *2* *3* *4* *5*

Strongly Disagree *Strongly Agree*

a. _____ Working in small groups is better than working alone
b. _____ I like my work best when I do it myself
c. _____ I prefer tasks that allow me to work with others
d. _____ The less I have to rely on others, the happier I am

Appendix B

Post-survey of Student Perceptions

Name: _____ **Current MPL Level:** _____

Please complete each item in this evaluation and provide comments/suggestions to improve the program. Thank you for your cooperation.

Use the Likert scale of (1-Low, 5-High) for all the questions unless otherwise specified

1. How well prepared for the engineering undergraduate program do you feel you were as a result of attending the math tutoring program?

1 (Low) *2* *3* *4* *5 (High)*

2. After attending this program, compared to other college-bound students in your high school's math and science courses, rate yourself on each of the following traits:

1 (Low) *2* *3* *4* *5 (High)*

a. _____ Ability to set and reach goals
b. _____ Leadership abilities
c. _____ Competitiveness
d. _____ Communication skills
e. _____ Ability to work cooperatively
f. _____ Mathematical abilities
g. _____ Self-confidence (social)
h. _____ Self-confidence (intellectual)

3. After attending this program, please indicate the extent of your agreement with the following state ments:

1 (Low) *2* *3* *4* *5 (High)*

a. _____ Working in small groups is better than working alone
b. _____ I like my work best when I do it myself
c. _____ I prefer tasks that allow me to work with others
d. _____ The less I have to rely on others, the happier I am

4. As a result of attending this program, I have a better understanding of math concepts.

1 *2* *3* *4* *5*

Strongly Disagree *Strongly Agree*

Comments: _____

5. Attending the math tutoring prorgram helped me to develop my problem solving and analytical skills

1 *2* *3* *4* *5*

Strongly Disagree *Strongly Agree*

Comments: _____

6. Rate your interest in the evening activities offered during the math tutoring program.

1 (Low) *2* *3* *4* *5 (High)*

Comments: _____

_____

7. How many evening activities did you participate in during the week? _____

8. Rate the extent to which professors were helpful in the math sessions

1 *2* *3* *4* *5*

Not helpful *Very helpful*

Comments: _____

_____

9. Rate the extent to which student leaders were helpful in the math sessions

1 *2* *3* *4* *5*

Not helpful *Very helpful*

Comments: _____

_____

10. Rate your experience and the overall quality of the residence hall. (If applicable)

1 (Low) *2* *3* *4* *5 (High)*

Comments: _____

_____

11. What is your overall evaluation of the math component in math tutoring program?

1 (Low) *2* *3* *4* *5 (High)*

Comments: _____

12. Did you have fun during math tutoring program? Why or why not?

Yes *No*

Comments: _____

13. Did the math tutoring program meet your expectations? Why or Why not?

Yes *No*

Comments: _____

14. On a scale of 1 to 5, how likely would you recommend the math tutoring program to future incoming freshman students?

1 *2* *3* *4* *5*

Not likely to recommend *Definitely recommend*

Comments: _____

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