Stimulating Pre-College Interest in Science, Engineering and Mathematics through Space-Oriented Activities

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Abstract

The City of El Paso is a rapidly growing community located on the US-Mexico border that has a largely Hispanic population. The region can be categorized as under-educated and socio-economically disadvantaged. For a number of reasons, most students graduating from El Paso area high schools are under-prepared in mathematics and science and thus are at a disadvantage in pursuing engineering programs at the post secondary level.

The Texas PreFreshman Engineering Program (TexPREP) seeks to identify high-achieving middle and high school students with interests in science, engineering and mathematics and to enhance their preparation in these fields and thus increase their likelihood of succeeding in college. TexPREP is an academically intense eight-week summer program, which stresses the development of abstract reasoning, problem solving skills, and their applications.

The Pan American Center for Earth and Environmental Studies (PACES) is a NASA University Research Center on the UTEP campus. In addition to its mission to contribute research in support of NASA's Earth Science Strategic Enterprise, PACES seeks to promote science, engineering and mathematics awareness among K-12 students, especially those with minority and socio-economically disadvantaged backgrounds.

In 2001, collaboration between TexPREP and PACES began with the objective of using activities with space-oriented themes as a means to stimulate student interest in science, engineering and mathematics. Over the past two summers, a variety of activities have been conducted. These include (1) Remote sensing and image interpretation, (2) CricketSat electronic telemetry device activity, (3) Protein Crystal Growth experiment, (4) Rover design competition (5) "Mission to Mars" play, and (6) Field trips to NASA facilities. This paper presents a description of these space-oriented program components and some results from the evaluation of the program.

1. Introduction

Underrepresented minorities now compromise over 25% of the U.S. population. This proportion is projected to continue upward. From more than one-fourth of the total population, underrepresented minorities compromised only 12% of the baccalaureates awarded in engineering in 2000. Additionally, females of all ethnic backgrounds remain underrepresented in the engineering and technological workplace. Over the past several decades, the need to increase minority and female participation in engineering has taken center stage. An increase in minority and female participation in engineering is needed in order to help fill the numerous positions in

high-tech industry. Educators and industry leaders believe the solution lies in education[1]. Young people need preparation in science and mathematics *before* they get into higher education – and before they begin flowing out into the workforce, unprepared and unqualified to fill positions in high technology industries[2]. If we want more females and minorities to take an interest in technological fields, we must create a more inclusive view of engineering and technology. The first step is to debunk the stereotype of the "computer nerd" by depicting the broad array of career options in science and technology[3].

El Paso is a city of over 700,000 in the El Paso – Juarez, Mexico metroplex of almost 2 million. It is the fifth largest city in Texas and is one of the fastest growing metropolitan areas in the nation. Recent census data shows that the area is 70% Hispanic, 3% African American and 1% Native American. Over 50% of the households speak Spanish as the language of preference and an estimated 30% of the adult population is functionally illiterate. A vibrant community, enriched by its ethnic diversity, the region is, however, marked by high levels of poverty, unemployment and academic underachievement. El Paso County has 9 school districts including both urban and rural populations. The three largest districts, El Paso, Socorro, and Ysleta Independent School District, serve more than 130,000 students of which 85% are Hispanic. The 6 small rural districts, Anthony, Canutillo, Clint, Fabens, San Elizario, and Tornillo Independent School District serve 20,000 students and are 96% Hispanic. In the area of social and economic factors, there are suggestions from studies that have shown that poor and minority students are more likely to attend schools with severely limited resources and less well-prepared teachers, more likely to be sorted into low academic tracks that limit their access to advanced mathematics and science courses, and less likely to attend schools that offer these advanced courses. In spite of recent gains nationally in mathematics and science achievement, there still remains a discrepancy between students of different demographic backgrounds. Asian Americans, Pacific Islanders and white students outperformed Black, Hispanic, and Native American Students – even when comparisons correct for the disparities in the courses students have taken[4].

2. Texas PreFreshman Engineering Program

The purpose of the Texas Prefreshmen Engineering Program El Paso chapter is to identify high-achieving middle and high school students with an interest in engineering, science, and other mathematical fields of study and to increase their knowledge of job opportunities in these fields in the El Paso area and beyond. The El Paso Chapter of TexPREP is one of eleven TexPREP sites that operate around the State of Texas. The statewide office is located in San Antonio.

TexPREP is an academically intense eight-week summer program. It provides middle and high school participants with educational opportunities in Science, Mathematics, Engineering, and Technology (SMET) disciplines that transcend what are offered in the regular academic year. TexPREP activities are designed to stress the development of abstract reasoning, problem solving skills, and their applications. The program encourages the participation of underrepresented minority and female students. The program participants are high school and middle school students from the various independent school districts and the private schools of the El Paso area.

A student may participate in TexPREP for a maximum of three summers. Students are organized into three groups (Year 1, Year 2, and Year 3) based upon years of program participation. Different activities and curricula are planned for each of the three groups.

2.1 Program Goals

The goals for El Paso TexPREP program are the following:

- To acquaint student participants with professional opportunities in engineering;
- To reinforce the mathematics preparation of these students at high school and college levels
- To increase the number of competently prepared students from the El Paso area who will ultimately pursue engineering studies in college;
- To increase the retention rate of these students as they progress through college.
- To recruit participants from the school districts in and around El Paso with special efforts made to attract female students and students from minority groups who have been traditionally underrepresented in the professional engineering and high technology areas.

2.2 Program Curriculum Components

TexPREP provides a curriculum that seeks to better prepare its participants for future college studies. The bulk of the curriculum is centered in mathematics preparation and it introduces topics that are not normally offered during the regular academic year. For example, participants are introduced to concepts from calculus mathematics through an innovative approach known as Visual Calculus. By completing all three summers of TexPREP, students will have received instruction in following subjects:

- *Logic and Its Applications to Mathematics:* A daily lecture class required of Year 1 participants.
- *Visual Calculus:* A visual, hands on approach to calculus concepts for Year 1 participants.
- *Algebraic Structures:* A daily lecture class required of Year 2 participants.
- *Introduction to Engineering:* A four-week daily lecture/laboratory class with topics in Engineering. This component incorporates design projects for Year 1 students.
- *Introduction to Computer Science:* A four-week daily lecture/laboratory class in writing computer programs. This component is required for Year 1 and Year 2 participants.
- *Topics in Problem Solving:* A daily, small group, seminar class for all participants. Problem solving was thematic using a "Mission to Mars" and how TexPrep skills applied to this.
- *Research and Study:* Daily small group classes giving students time to work on class assignments, computer projects, or engineering modeling projects.
- *Introduction to Physics:* A daily lecture laboratory class with topic on physics and design projects in Physics required of Year 2 participants.
- *Technical Writing:* A daily writing class required for Year 3 students.
- *Statistics and Probability:* A daily lecture class required for Year 3 participants.

In addition to the required educational components, the program regularly schedules presentations from invited guest scientists, engineers, business leaders and community leaders. The primary purpose behind the guest presentations is to acquaint the student participants with career opportunities in SMET fields.

3. TexPREP/PACES Partnership

A theme expressed in NASA's mission statement is "to stimulate the next generation of explorers as only NASA can." The exploration of space is one of man's greatest endeavors and can be used effectively to encourage students to study SMET courses. In 2001, a partnership was formed between TexPREP and the Pan American Center for Earth and Environmental Studies (PACES), a NASA University Research Center located on the UTEP campus[5]. The TexPREP/PACES Partnership was formed in an effort to strengthen the preparation of TexPREP students through their participation in "space-oriented" activities. In line with NASA's philosophy on stimulating students, these activities have been designed to capitalize on space themes in order to motivate students to remain in the SMET pipeline and eventually obtain degrees in SMET fields. The following sections introduce and provide a brief description of activities that have arisen through the TexPREP/PACES Partnership.

3.1 Remote Sensing

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a sensor that is not in contact with the object, area, or phenomenon under investigation. Through a remote sensing activity, Year 2 students gained computer skills through their use of a commercial remote sensing software package, ER Mapper. They also gained an improved understanding of the electromagnetic spectrum and how it applies to applications such as remote sensing and image interpretation. The activity involved remotely sensed imagery of the El Paso-Ciudad Juarez border region and thus students acquired an increased appreciation of the geography, geology, and environment for the area in which they live.

Briefly stated, the project involved teams of 4 students who conducted a remote sensing project using Landsat TM data for the El Paso-Ciudad Juarez border region. Landsat TM data consisted of measurements in seven spectral bands in the range from 0.45 μm (blue) to 12.50 μm (thermal infrared) of the electromagnetic spectrum.

To begin, the instructor presented a lecture that explained the foundations and applications of remote sensing. Various exercises emphasizing the importance of resolution and pixel size were assigned[6]. These included exercises whereby students estimated the area and mass of polar ice caps, lakes, forests, and other features present in remotely sensed imagery.

An understanding of the principles of light and the electromagnetic spectrum is fundamental to the interpretation of remotely sensed images. The relationships among the various colors and wavelengths for visible light were presented. Students explored these concepts by mixing different colors of light using Luxagon light boxes.

Next, students learned the basic features of ER-Mapper, a widely used commercial remote sensing software package. Using ER-Mapper, students processed various Landsat TM files to produce true color and false color composite images. After gaining experience with ER-Mapper, teams of students began processing Landsat-TM data obtained from the El Paso-Ciudad Juarez border region. To begin, students produced true color images of the region. Using these true color images, students were asked to locate familiar landmarks in the image. Landmarks included airports, neighborhoods, parks, golf courses, and other physical and geological features. Often, these landmarks could not be easily located in the true color image. Next, students processed the Landsat data using combinations of bands that involve those in the visible range of the electromagnetic spectrum as well as bands in the infrared region. Using the false color images that were produced, students were called upon to identify once again a variety of significant landmarks in the area. Through their observations, students learned the advantages of using the false color over the true color images for the purpose of identifying landmarks.

Each student group was asked to contribute what they considered their most aesthetically pleasing false color image to a competition. A winner was selected from the contributed images. This image was then copied and transferred onto T-shirts, which were distributed to all students.

3.2 CricketSat Activity

In order to provide Year 3 students with an appreciation of the electronics, a project was implemented whereby they constructed a circuit called a CricketSat. The CricketSat was designed by Dr. Bob Twiggs, Director of the Space Systems Development Laboratory of Stanford University and is a low cost, fully functioning telemetry device. It allows students to experience actual data collection, recovery, and analysis[7]. The circuit is akin to the type of circuit that one might see onboard an actual spacecraft or rover. It incorporates a temperature sensitive resistor, known as a thermistor, an integrated timer circuit, a variety of passive components and a light emitting diode (LED). The circuit is capable of measuring temperature.

Teams of three students began the exercise by learning the fundamentals of soldering and laboratory safety. Once the students were "certified" by conducting some simple soldering assignments, they could begin the construction of the CricketSat. The various electronic components of the circuit were soldered on a printed circuit board to create the CricketSat.

The CricketSat's LED pulses at a rate that is linearly proportional to temperature. It pulses at a rate of approximately 2 Hz at room temperature. The pulse rate increases for higher temperatures and decreases for lower temperatures. Once their circuits were assembled, teams of students were given stopwatches and thermometers. They were asked to collect and record pulse rate data along with temperature at a number of sites around campus.

Once the data was collected, the students were asked to graph it and develop a mathematical relationship between pulse rate and temperature. This aspect of the project was valuable in that it allowed students to "discover" the linear relationship between pulse rate and temperature. It also brought real-life meaning to modeling the relationship between physical quantities using mathematics.

As a consequence of the exercise, student became familiarized with the various components (resistors, capacitors, inductors, integrated circuits, etc.) that comprise the electronic device. The exercise strengthened laboratory skill of students such as reading and understanding electronic schematics, determining resistor values, and soldering components on a printed circuit board. Lastly students gained an appreciation in how empirical data is recorded, analyzed and modeled.

3.3 Protein Crystal Growth Experiment

Biotechnology is an area whose importance in addressing problems in health, agriculture, and the environment is expected to increase in the future. For several years, the Texas Space Grant Consortium has sponsored a State-wide Protein Crystal Growth Experiment as a means for stimulating student interest in biotechnology and microgravity. This highly successful educational outreach program has engaged thousands of students and teachers during the academic year. Through the Texas Space Grant Consortium, the Protein Crystal Growth Experiment was made available for Year 2 and Year 3 TexPREP students.

The activity consisted of several components that will be briefly described. To begin, an overview of protein crystallization was presented. The advantages of growing protein crystals in the microgravity environment of space were explained. Students were divided into eight groups of four students each. Each group prepared super-saturated solutions of lysozyme, a protein found in human tear ducts, in mucous, and in chicken embryos. These eight solutions were distinguished by adding different amounts of salt, which acts as a precipitant, to each lysozyme-buffer solution. Each group transfered its solution to eight small culture tubes. The groups then traded tubes so that in the end each group had a crystallization screen comprised of eight different salt concentrations.

Using the scientific methods, students hypothesized about which salt concentration level they believed would produce the biggest crystals. Students made daily recordings of their observations of crystal size and prevalence. After two weeks of observations, students were instructed to draw conclusions and to write an essay about the activity. Each essay included a description of the experiment, their hypotheses, their data collection methods, and experiment results. Students conducted research primarily through the internet on the topics of protein crystallization, microgravity, NASA's biotechnology program, and careers in biotechnology. These topics are introduced into their essays. The essays were graded and the top twenty essays were identified.

The twenty winning essayists were invited to participate to an actual flight sample loading that was conducted by scientists and engineers affiliated with the NASA Marshall Space Flight Center. The flight sample loading was held during the final week of TexPREP. The flight samples were frozen so that they could then be flown to the International Space Station via the Space Shuttle. The twenty students were promised a trip to Cape Kennedy to witness the launch of their samples. Because of the grounding of the Shuttle fleet due to the Columbia accident, the samples have yet to be delivered to space. However, the students still received VIP invitations to Kennedy Space Center. This trip was conducted the following spring.

3.4 Rover Design Competition

Year 1 students participated in a competition to design and construct a rover capable of traversing a desert terrain. The students were provided with a box of "Lego" robot parts from which they constructed their design. The parts included beams, axles, gears, wheels and tires. Students were also given two reversible 9-volt stepper motors with controllers. The wheels on each side of a rover could be turned independently using the motors. This enabled the rover to be turned and guided by the operator using the motor controller.

A competition was held to determine the overall best design. The competition was named the "Ray Bell Robot Classic" in honor of a recently retired UTEP professor who taught robotics. A track course was laid out that included a number of turns, elevations, and obstacles. The rovers were required to navigate the track course with the rover turning in the best time being declared the winner. Reporters from the University's News and Publication covered the event.

3.5 "Mission to Mars" Play

At the end of each summer, student participants write and conduct a play with a space theme. Special sets, props and costumes are designed and constructed. The play is designed to contain information about space and NASA that the students have learned through their summer experience with TexPREP. This past year, students constructed a mock flight deck for their spacecraft. The play presented aspects of day-to-day life on a "Mission to Mars." The play was dedicated to the memory of the Columbia astronauts. It was presented to fellow students and parents at a UTEP assembly hall.

3.6 NASA Field Trips

Experience has shown that field trips serve as a tremendous motivator for students to continue with the program from one summer to the next. For many participants, these field trips represent their first venture beyond the city limits of El Paso. TexPREP has successfully integrated NASA into the field trips for Year 2 and Year 3 students. Year 2 students visit the Alamorgordo Space Center, located approximately 120 miles from El Paso. At the Alamogordo Space Center, they tour the space museum and attend an IMAX movie presentation about space. Year 3 students visit Space Center Houston were they learn about the Johnson Space Center. As part of the tour, they experience demonstrations and lab experiments concerning physics in space, thermodynamics, and other related topics.

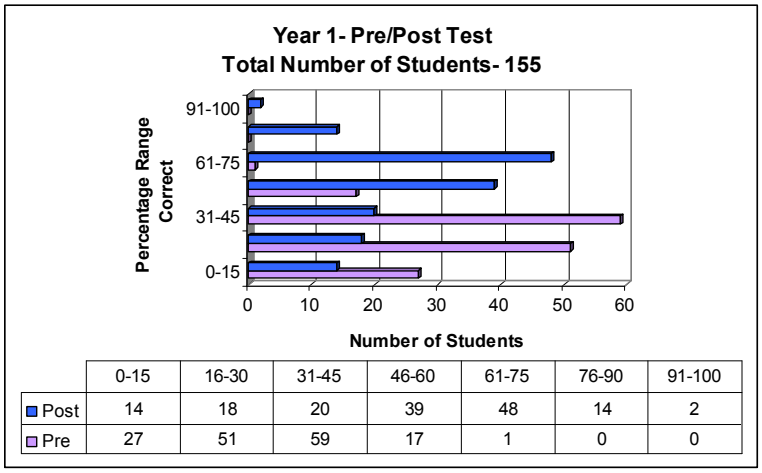
4. Evaluation

In an effort to evaluate the effectiveness of the TexPREP program, an evaluation plan has been developed[8]. The plan consists of pre- and post-tests in mathematics, along with surveys of student attitudes and beliefs. Examination of the pre- and post-test results can provide insight into any gains in performance that students may experience as a result of the academic components of the program. Student responses to the survey instruments are seen as a means for gauging the effectiveness of program activities whose goals were to nurture student interest in SMET courses and careers.

The results that follow were obtained from the responses of TexPREP participants for the year 2003. Of the 281 students who were accepted into and began the program, 245 successfully completed the program. Responses of the students who began but did not complete the program are not included in the evaluation. Of the 245 completers, there were 205 Hispanics, 24 Anglos, 8 African Americans, 5 Asians, and 3 Native Americans. The group consisted of 131 females and 114 males. There were 155 Year 1, 61 Year 2, and 29 Year 3 students who participated in the evaluation.

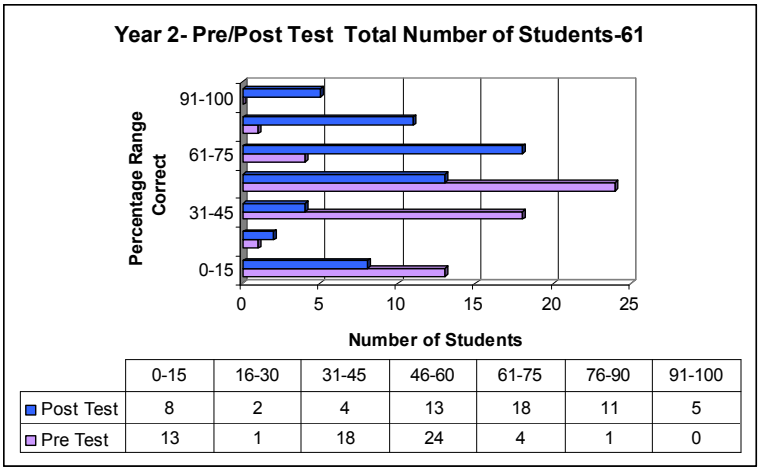
It is well recognized poor K-12 preparation in mathematics can seriously impact the likelihood of a student successfully entering and performing well in a SMET major in college. As was indicated earlier, a great deal of attention is focused toward preparing students mathematically through the TexPREP mathematics components. It is also important to emphasize to students the important role that mathematics plays in the various activities conducted through TexPREP. Such emphasis hopefully serves to motivate students to view mathematics as a basic tool for science and engineering.

Students were given pre-tests and post-tests in the area of mathematics. The examinations consisted of approximately 25 multiple-choice questions over topics in mathematics appropriate to grade level. Tables 1-3 document the results on pre and post-testing by student classification. It should be noted that only students taking both the pre- and post-tests in mathematics were included in the results.



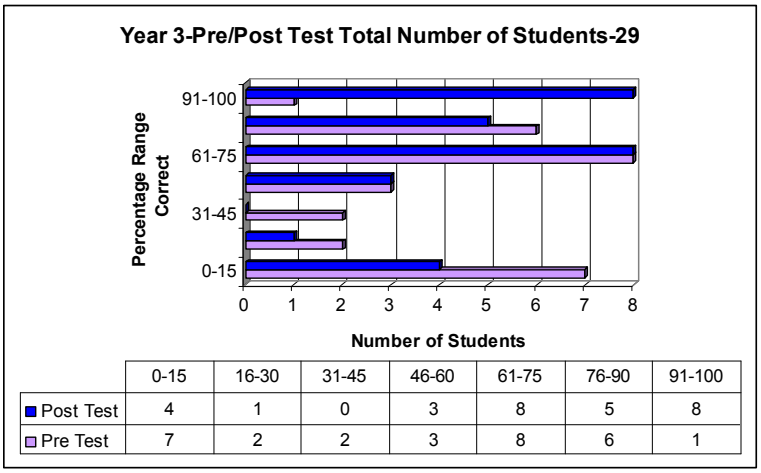
	0-15	16-30	31-45	46-60	61-75	76-90	91-100
Post	14	18	20	39	48	14	2
Pre	27	51	59	17	1	0	0

Table 1: Year 1 Pre- and Post-Test Results for Mathematics



	0-15	16-30	31-45	46-60	61-75	76-90	91-100
Post Test	8	2	4	13	18	11	5
Pre Test	13	1	18	24	4	1	0

Table 2: Year 2 Pre- and Post-Test Results for Mathematics



	0-15	16-30	31-45	46-60	61-75	76-90	91-100
Post Test	4	1	0	3	8	5	8
Pre Test	7	2	2	3	8	6	1

Table 3: Year 3 Pre- and Post-Test Results for Mathematics

All three tables reveal a significant improvement in the percentage of correct responses on the post-test. Year 1 students (Table 1) displayed the most significant improvement on the post-test. Whereas just one Year 1 student recorded a percentage of correct responses in excess of 60% in the pre-test, 64 students recorded correct responses in excess of 60% on the post-test.

Tables 4-7 present the results of student responses to statements related to the program. These responses were solicited in an attempt to capture some degree of how effective the TexPREP program was in developing student interest in SMET subject areas and careers.

Table 4 indicates that students perceived that their mathematical skills were indeed reinforced by the TexPREP curriculum. It is interesting to note that the percentage of student agreeing with this belief increased with the number of years the student had been with the program. Almost 90% of Year 3 students were in agreement with the statement.

		The curriculum reinforced my mathematical skills.		Total
		agree	Disagree	
PREP 1	N	124	31	155
	%	80.0%	20.0%	100%
PREP 2	N	51	10	61
	%	83.6%	16.4%	100%
PREP 3	N	26	3	29
	%	89.7%	10.3%	100%
TOTAL	N	201	44	245
	%	82.0%	18.0%	100%

Table 4. Perception of Mathematical Skills

Table 5 indicates that over 70% of participants agreed that the program had improved their problem-solving skills. This percentage was less than that observed in the case of improvement of mathematical skills.

		PREP improved my problem-solving skills.		Total
		Agree	disagree	
PREP 1	N	112	43	155
	%	72.3%	27.7%	100%
PREP 2	N	42	19	61
	%	68.9%	31.1%	100%
PREP 3	N	21	8	29
	%	72.4%	27.6%	100%
TOTAL	N	175	70	245
	%	71.4%	28.6%	100%

Table 5. Perception of Problem Solving Skills

		The program increased my knowledge of math-based professions.		Total
		agree	disagree	
PREP 1	N	141	14	155
	%	91.0%	9.0%	100%
PREP 2	N	53	8	61
	%	86.9%	13.1%	100%
PREP 3	N	23	6	29
	%	79.3%	20.7%	100%
TOTAL	N	217	28	245
	%	88.6%	11.4%	100%

Table 6. Knowledge of Math-Based Professions

Table 6 shows that the program was particularly effective in increasing the knowledge of math based professions. It is interesting to note that the percentage of students agreeing with the statement diminished with each year of participation in the program. This trend could be explained by the fact that many of the participants had very little knowledge of math-based professions prior to enrolling in TexPREP. This is often the case for students residing in an area such as El Paso where high-tech industry is not the norm. We feel that the field trips and guest speakers components are particularly effective in acquainting students with math-based occupations.

		This program reinforced my desire to study engineering, science, or math.		Total
		agree	disagree	
PREP 1	N	109	46	155
	%	70.3%	29.7%	100%
PREP 2	N	42	19	61
	%	68.9%	31.1%	100%
PREP 3	N	24	5	29
	%	82.8%	17.2%	100%
TOTAL	N	175	70	245
	%	71.4%	28.6%	100%

Table 7. Continued Study of Engineering, Science or Math

Table 7 indicates that over 70% of participants felt that the program was effective in reinforcing their desire to study engineering, science or math. It is interesting to note that 82.8% of Year 4 students agreed with the statement. Year 3 students tend to be closer in time to entering college. It is possible that Year 3 students spend more time reflecting on college and career choices than the younger students in Years 1 and 2.

Since the origin of the TexPREP Program in 1979, over 20,000 students have completed at least one summer component at one of the eleven sites around the State of Texas[9]. Of the 11,033 former participants who are of college age, 5,380 responded to a survey in 2002. This survey revealed that:

- 99.9% graduated from high school.
- 88% are college students (2,661) or university graduates (2,059).
- 76% of the college graduates are members of minority groups.
- 51% of the college graduates earned degrees in science, mathematics or engineering.
- 71% of the science, mathematics and engineering are members of minority groups.

Though the 2002 survey referenced above included participants from sites other than El Paso, its results compare favorably with results obtained from a smaller sample of former TexPREP El Paso participants in 2003.

5. Conclusions and Future Plans

We are encouraged by the positive results of the evaluation for TexPREP. Over the past five years, the number of students participating in TexPREP has more than doubled. We anticipate that more than 300 students will enroll in Summer 2005. Other evaluation data reveal that the overwhelming majority of participants go on to college and many eventually earn degrees in SMET areas. Considering the high percentage of underrepresented minorities and females in the program, we feel that this is an important achievement.

We intend to continue to incorporate NASA themes into TexPREP activities and curricula. We feel that it serves as an excellent motivator for young people. We do plan to experiment with new space-related activities. One activity that is planned for Summer 2005 is one that centers on the construction of a Solar Powered Golf Cart. There are numerous golf carts that are operated by the Building and Grounds and the Athletics Departments on the UTEP Campus. We intend to involve students in the retrofitting of one of these golf carts to operate on solar power. We will draw parallels in this project to those of NASA rovers operating on the Moon and Mars. Students will gain an appreciation for solar energy, green engineering, and space exploration through this project.

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