Recruitment and Retention of Underrepresented Students to a Career of Research in Engineering and the Sciences

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Abstract

We wish to present a program designed to encourage pre-college students to major in engineering and to consider research as a career track. We will give a description of the program and how it was mounted. It is our objective in this presentation to demonstrate that a program tailored for our institution is flexible enough to be adapted to fit many other universities.

I. Introduction

The City College of the City University of New York has long been a viable means for underrepresented groups to advance socially and professionally. The geographic area in which the university sits allows the school to draw its enrollment from one of the highest concentration of minority groups in the nation. City College has been and continues to be a major source of underrepresented undergraduates who go on to earn the Ph.D. degree. It is generally accepted that the most effective time to encourage young people to consider careers in engineering and the sciences is during the pre-college years. SPISE-CREAM (Select Program in Science and Engineering-Careers in Research Encouragement and Mentoring) is directed toward pre-college students, exposing them to engineering and the research experience. The program, while directed at high-school juniors, has attracted high-school seniors and sophomores. By linking to undergraduate research programs that feed minority students into graduate programs, SPISE CREAM creates a minority Ph.D. pipeline.

II. Program Description

The SPISE-CREAM program is a ten week Saturday program sponsored in part by the General Electric fund and the NSF sponsored coalition ECSEL. The instructional staff consisted of two professors (one civil engineer and one electrical engineer) from the school of Engineering at the City College of New York, a high school science teacher from the New York City Public School system and four undergraduate students. The students were given a hands-on feeling for the nature of research and design through work on a project in a team and mentoring environment. The project encompasses concepts and principles from various engineering disciplines (i.e. computer science, mechanical, electrical and civil engineering). The program encourages pre-college students to major in engineering at City College and to consider research as a career track. During the application process candidates had to submit an application form, two letters of recommendation from a high school teacher or administrator, a short essay, answer a questionnaire, and go on an interview with a CCNY faculty or staff member. After receiving notification of acceptance into the program each participant is required to take a math and engineering aptitude examination. The examination helped to determine the level of the advanced tutorial courses the successful applicants would receive during the first part of the ten week program.

SPISE CREAM sessions were held on Saturdays from 9:00 a.m. to 2:00 p.m. and included lunch, free of charge. An opening ceremony was given for the participants and their parents. This provided an opportunity to involve the parents of the participants in the education of their children, as well as answer any questions they may have had regarding the program. Both parents and students were given an overview of the program and what we hope to achieve. The 22 participants divided themselves into four design teams. Each team chose a name for their group (i.e., “GT Drag-On”, “Pentium 2K). An undergraduate student was assigned to each team to serve as a mentor and role model and to help the participants through the rigorous program. Each team had to design and build a solar vehicle. Below in figure 1 the schedule and syllabus of the program is shown. In figure 2., the statement of the problem is shown. In figure 3., the method in which the vehicles were tested and evaluated can be seen.

Before each tutorial, components (i.e. photocells, gears, motors, test equipment) relating to the topic were distributed to each team. As the professor lectured the students were allowed to examine and experiment with the parts that would be used to build their solar vehicle. Lecturing was kept to a minimum in order to promote interaction between the students, the group leaders and the faculty members.

A typical day for a SPISE CREAM scholar would entail an hour or more session on topics ranging from “Basic Circuit Theory” to “ Experimental and Investigative Methods”. Then another two hours of characterizing the components of their solar vehicle, such as determining the relationship between the input light energy to the output voltage/current of a solar cell. The balance of the day would be used to work on the design of the vehicle. Strict guidelines were given as to the size of the vehicle and what materials could be used in its construction. The students were given instructions in the form of a design brief, as shown in figure 4., and figure 5., on how they should go about designing and building their vehicle. They were required to keep an accurate log of their experimental set-ups and experimental results. Preliminary designs and ideas were also written in the diary, as well as scientific observations. After weeks of learning new concepts in science and engineering and incorporating them into the design of their solar vehicle each team competed against each other in a solar vehicle tournament. The cars were judged based on the criteria stated in figure 3. The teams were judged based on the vehicle performance, their poster presentation, their scientific knowledge of the vehicle and its components. Three faculty members from the school of engineering were the judges.

III. Group Dynamics

While the study of group dynamics is not the major thrust of this work we feel that some discussion of it can be useful. Aspects of a cooperative learning environment were incorporated into the lessons and activities of the SPISE-CREAM program. The Cooperative learning model has been demonstrated to be an effective tool in engineering education[1, 2]. This model is based on the premise that students learn best when they work as a team rather than through a one way transmission process. In a cooperative setting students support each other by providing alternative ideas and expertise. It has been reported that structured cooperative learning improves student's understanding of course material as well as their communication and teamwork skills[3].

In the SPISE-CREAM program the interaction between the students in the different design groups varied significantly. In some groups there was a strong team spirit, where each member of the group worked for the common good of the team. These groups tended to complete each task in an efficient manner with little conflict among the members of the team. The lab books of the members of these teams were usually very organized. These teams also tended to be very confident and ambitious. One group was so confident, that they went with a doomed design for their vehicle until the ninth week of the program, before deciding that they would need to simplify it. In many respects these groups fit the cooperative model. The team members discussed at great length how they might go about solving design problems. The work -load was shared and distributed according to the member's talent and on average each member was well informed about the project. These teams also appeared to enjoy their workday more often.

In other groups, the teams had very little team spirit. These groups tended to be very disorganized and inefficient. The work -load was not shared equitably. One or two team members would dominate the project and there was very little sharing of ideas. Knowledge about the project and scientific concepts tended to be uneven among the members of these groups. On occasion it was necessary for a group leader or a faculty member to intervene in order to resolve a dispute among a team. In general, the disputes were about the distribution of work or the manner in which an experiment should be done. For these groups the collaborative model does not seem to fit as well. However, in a recent study on the interaction dynamics among students in engineering work groups by Cynthia R. Haler et al., the authors have identified two interaction modes of peer teaching and learning[4]. In the first mode, *transfer-of-knowledge sequences* (TKs), students take the roles of teacher and pupil, and in the second mode, collaborative sequences (CSs), no such differentiation exists. It is the conclusions of these authors that: 1) student learning is enhanced by the feedback loop of TK sequences and the sharing of new knowledge generated in CS sequences and 2) an imbalance in the interactional modes can lead to interpersonal problems in the group. These conclusions give some insight as to why some of the SPISE-CREAM teams had difficulty in working together.

The team dynamics of the individual groups were not static. As the deadline approached and the pressure built each team ultimately began to find ways to work together. During the later part of the program, conflicts between team members where due more to panic attacks than to some of the issues mention above. These small disputes became less and less common and tended to resolve themselves. By the last day of the program, the day in which the tournament was held, each team was ready to compete.

IV. Concluding Remarks

The objective of the program was to attract high school students to a career in engineering and research. We feel that this goal was met. Of the original 22 students 18 completed the program. The four students that did not complete the program left early on. They had either enrolled in other Saturday programs in the tri-state area or were not willing to make a commitment to the SPISE-CREAM program. Of the eight high school seniors in the program five went on to enroll in an engineering or science program. Four of the five are presently enrolled at the City College of New York (CCNY), three are engineering students and the fourth is a biomedical student. We are only able to track the progress of those students that are in the CCNY engineering school. These students become part of the Program for the Retention of Engineering Students (PRES). In the PRES program students are able to receive tutoring, counseling, internship, and guidance throughout their academic career. We believe that some of the students of the SPISE-CREAM program will eventually become tutors in the PRES program. Unfortunately we have no mechanism that would allow us to track those students that are not in our engineering program.

SPISE-CREAM

Major Objective:	Design of a solar powered car in accordance with specific performance criteria.
Program Duration:	10 weeks (Saturdays, 9AM - 2PM) (Additional contact hours encouraged)
Location:	Steinman Hall, 140th St. at Convent Avenue
Week 1:	
8:30-9:15AM	Breakfast; Welcome and Introductions
9:15-9:40AM	City College of New York Video; Questions/Answers
9:40-10:05AM	Program Overview/Rules and Regulations
10:05-10:15AM	Break
10:15-10:35AM	General Discussion (Engineering, Research, Goals)
10:35-11:15AM	Student Survey/Basic Practices Research Survey
11:15- 11:30AM	Selection of Groups
11:30AM-12:15PM	Lunch
12:15-1:45PM	Group Work (Design Problem and Discussion)
Week 2:	**Grouping Deadline** Workshop: a) Experimental and investigative methods; (40 min.) b) Basic Circuit Theory / Photocell operation; (40 min.) Lab session: Power Source, Characterization of Photo-panels (i.e. **V**oltage (V), **C**urrent (I), **P**ower (P) measurements)
Week 3:	**Workshop:** a) Electric motors: (40 min.) b) Gears: 45 min. Lab Session: Power Plant, Characterization of Electric Motors and gears.
Week 4:	**Workshop:** **a) How To Make A Technical Presentation. (40min)** b) Computer Programming, (1hr)
Week 5:	**Workshop:** Aerodynamics & Center of Gravity, (1hr) Lab Session
Week 6:	**Kinematics (1hr)** Lab Session
Week 7	Lab Session
Week 8:	Lab Session: Completion of Alpha Solar Car Testing and Evaluation
Week 9:	**Lab Session** Beta Solar Car Testing and Evaluation
Week 10:	Solar Car Tournament

Vehicles and Teams compete in several categories. (i.e. acceleration, speed, pulling power, efficiency, aesthetics aerodynamics (head wind), climbing (an incline), weight)

Figure 1. The SPISE-CREAM program outline.

Solar Car
Statement of Problem

Using the design process methodology and experimentation, each student (or team of students must design, construct using proper craftsmanship, test evaluate and redesign (optimize) a solar powered vehicle capable of carrying a payload, simulating cargo and people, along a test track in the shortest possible time under variable solar intensity. The design portfolio consisting of a lab notebook, drawings and data sheets will be used to document the student's work and serve as a basis for the assessment of the activity.

In designing the solar car the student/students will:

- Select a vehicle shape and size with dimensions not to exceed 12” x 10” x 12”
- Prepare a set of drawings for their design, which has a minimum of two views and includes all necessary dimensions
- Choose the use of either a gear or pulley driven axle or an air propeller

Specifications and Constraints

- Maximum size 12” x 10” x 12” (Length x Width x Height).
- Each car must be constructed from only the materials provided.
- A standard electric motor, propeller and solar cell(s), that will be provided, must be used.
- Electrical power is supplied to the motor by one or more solar cells.
- Cars must be able to operate under variable light conditions simulating clouds and overcast skies.
- Each car must carry a specified payload (ballast) simulating people and cargo.
- All cars must be designed to be as stable as possible.

Figure 2. The statement of the solar vehicle design problem.

Testing and Evaluation

The rules for testing are as such:

- Each car will be placed on a test track that's approximately 20 feet long.
- No one is permitted to touch the vehicle once it is released at the starting line.
- Each car should be capable of travelling the test track in a straight line without hitting the guidelines.

Each car will be evaluated based on the following tests and measurements:

- Speed (fastest, high rpm)
- Acceleration (quickest, high torque, high rpm)
- Gust Performance (aerodynamics)
- Incline Performance (high torque)
- Low Light Performance (efficiency)
- Pay Load (high torque)
- Tracking (travel a straight line)
- Vehicle Weight (Lightest)
- Aesthetics (style and beauty)

Figure 3. This sheet describes how the vehicles will be tested and evaluated.

Solar Car
Design Brief

A Design Criteria & Specifications

State the specifications which you will design your solar car to meet or exceed.
(These specifications should be as clear and direct as possible)

B Analysis of the Problem and Investigations

You must do the research that is required to develop at least two possible solutions (solar car design) that have the potential of meeting or exceeding the specifications. This research must include engineering concepts. The following listed concepts are provided as a starting point. *Do not limit yourself to the suggested concepts.*
Record all of your research including the source in your design portfolio (lab notebooks and data sheets).

Engineering & Scientific Concepts

- Basic Circuit Theory
- Solar Cell
- Newton's Laws of Physics
- Work & Energy
- Design Optimization
- Faraday's Law
- Good Craftsmanship
- Device Characterization
- Experimental & Investigative Methods
- Speed & Acceleration
- Drag
- Ohms law
- Trigonometry & Geometry
- Decision Making
- Design Loop
- Mechanical Drawing
- Aerodynamics
- Experimental Data, Errors, Graphs, & Tables

Investigations:
1) List all the questions that you believe must be answered to achieve a successful design.
2) List the resources used to research the engineering concepts and answer your questions.
3) Describe what you learned by conducting the above investigations.

C Design Considerations (possible solutions)

The goal of this phase of the design process is to develop at least two possible designs that may meet or exceed the design specifications. In developing the design you will have to look at many different tradeoffs such as:

Propulsion Tradeoffs	**Gear Train Tradeoffs**
· Motors (RPM vs. Torque) · Gear Driven Axle · Pulley Driven Axle · Air Propeller Driven (# of blades)	· Simple vs. Complex Gear Trains · Gear Ratio · RPM Level · Torque Level
Stability Tradeoffs	**Aerodynamics Tradeoffs**
· Weight vs. Traction	· Air Drag vs. speed · aesthetics · construction · solar cell performance

Figure 4. Page one of design brief.

Solar Cell Tradeoffs	Structure Tradeoffs
· Type of Solar Cell · Size of Solar Cell · Number of Solar Cells · Solar Cell Placement	· Strength Vs Weight · Ease of Construction · Aesthetics · Type of Structural Materials

Each of the possible designs should be complete. State and explain thoroughly (using engineering and scientific concepts) the reason for the selections of each item or decision that contributed to the overall design. A small sketch describing the design should be included. (This information should be written in your lab notebook)

D Chosen Design Optimization

The objective of this stage of the process is to decide which of the two proposed designs has the greatest potential of meeting or exceeding the design specifications.

1) Select the most promising design and state your reasons in engineering terms.
2) Provide two or three drawings showing different perspectives of the car. Include dimensions.
3) Referring to the engineering concepts investigated earlier, describe the chosen design. It may be necessary to perform certain calculations. As you produce the drawing and refer to the engineering concepts investigated earlier try to improve the design where ever possible.
4) State how some of your earlier lab investigations enabled you to improve the design.

E Testing & Optimization

In this part of the design process you will improve your solar car design as the result of test data. During testing it may become necessary to make additional design changes to increase the performance of your solar car.

Be sure to make only one change at a time and record each change and its effect on performance in an orderly fashion.

All of the data should be organized in charts and/or graphs in order to better analyze and maximize the solar car performance.

Important Data

- Car Speed
- Gear Ratio
- Motor Size & Location
- Payload
- Car acceleration
- Car Weight
- Pulley Ratio
- Solar Panel Size/Orientation
- Drag Force
- Speed & Torque

F Evaluation & Summary

This is the final step of the design portfolio. Here each team should organize all work for a presentation before fellow classmates/teams and instructors, and evaluate their design against the design specifications.

Figure 5. Page two of the design brief.

The SPISE-CREAM experience according to the students in the program was very positive. A number of the sophomores and juniors that were in the program have expressed a great interest in doing the program again. In one case a female high school student from Washington Irving, a local high school, wanted to attend the SPISE-CREAM program along with six of her friends. Each of them had participated in two other programs called SPISE and SPISE-Extended. Without question the faculty members of the SPISE-CREAM program found the experience both challenging and rewarding. It is the desire of the program administration and faculty to run the program again.

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